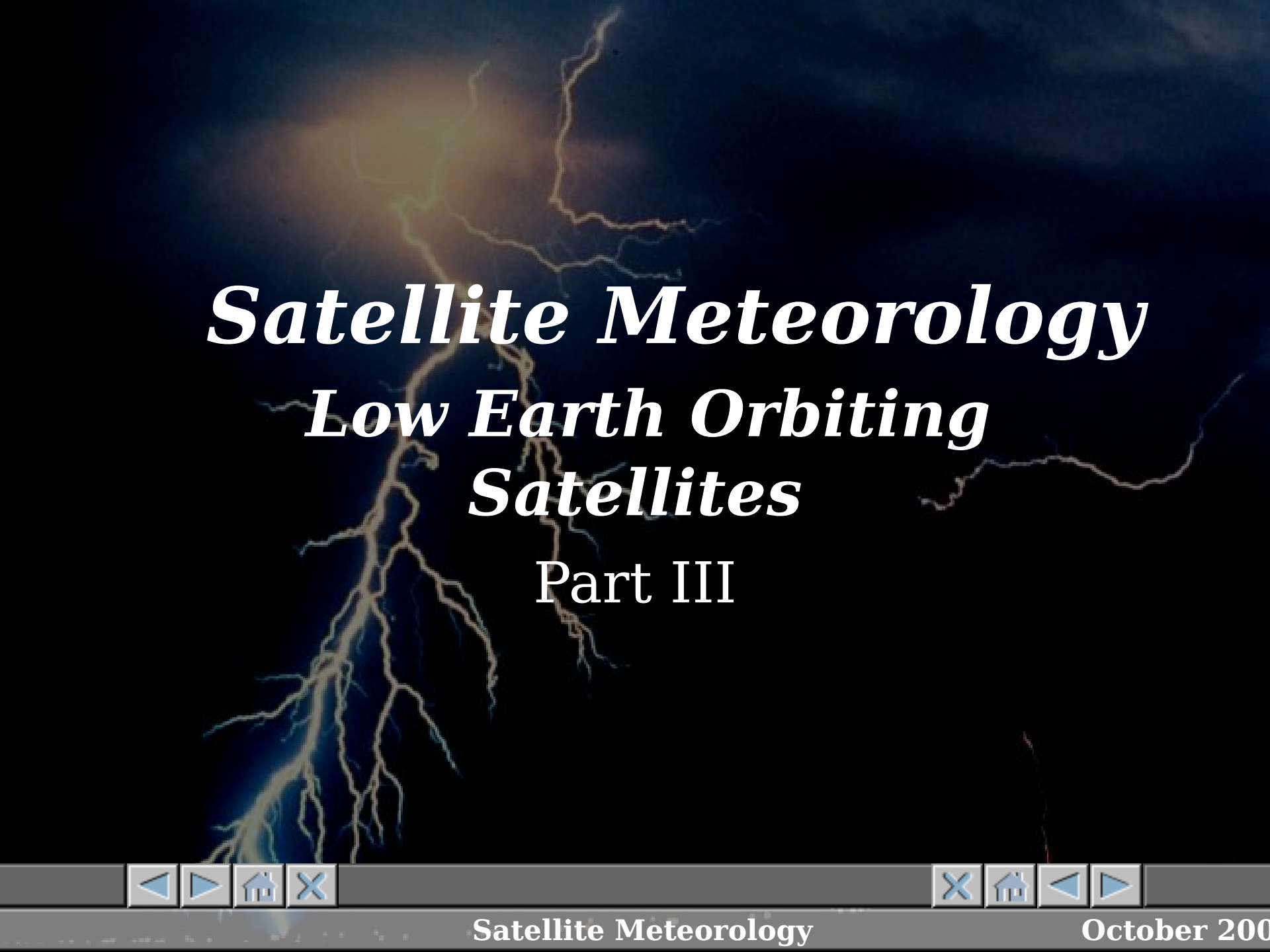


# *Satellite Meteorology*

## *Low Earth Orbiting Satellites*

Part III

# *Objective*

Understand basic concepts of low earth orbiting satellites, including orbits, characteristics, and products

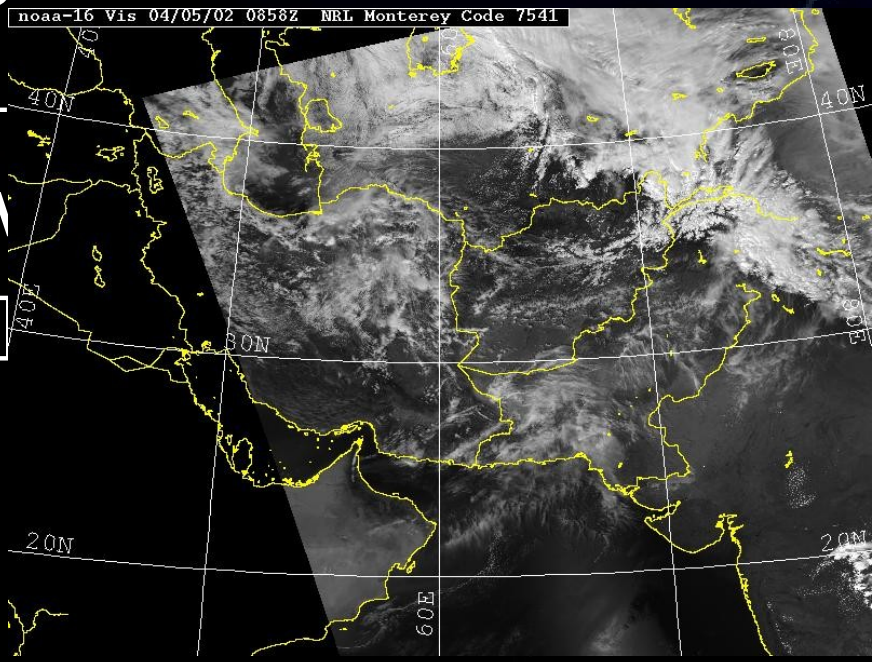
# *Overview*

Low-earth orbiting satellites (LEO), visible and infrared

- Advantages
- Disadvantages
- Characteristics
- Polar orbiters
- Operational satellit

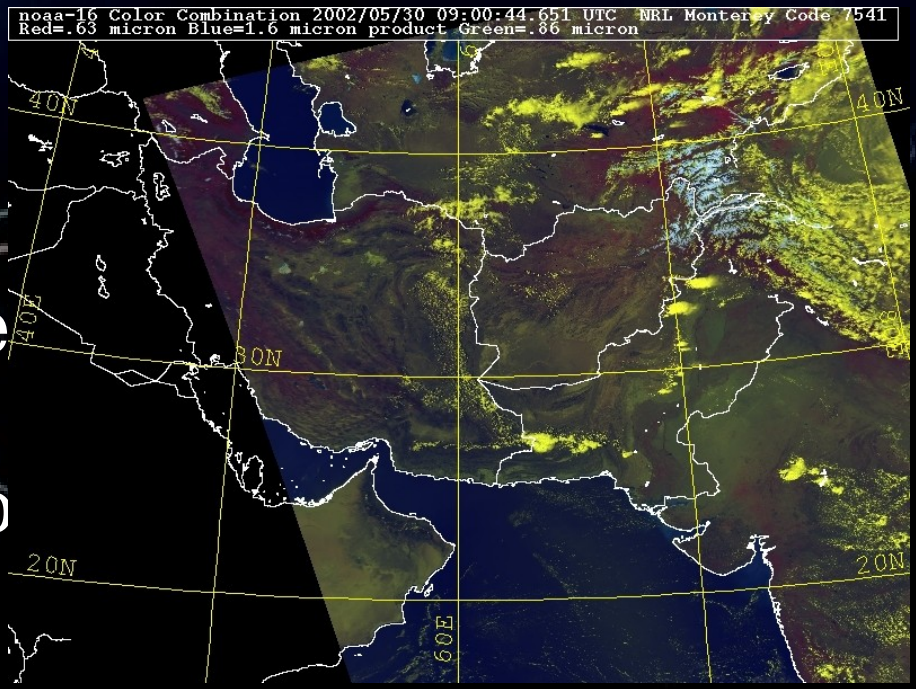
# *Advantages*

- Cover poles as well as tropics
- Worldwide coverage
- High spatial resolu
- Often carry microw
  Instruments as wel



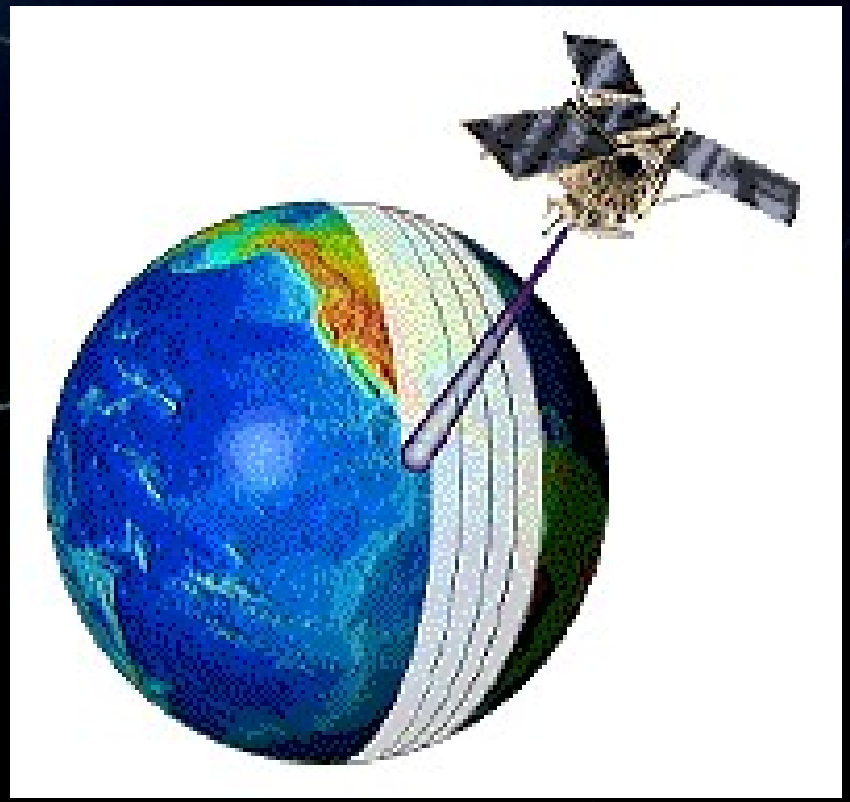
# *Disadvantages*

- Relatively narrow swath width
- As few as two views per day over a region (tropical coverage particularly poor)
- Little capability to loop images



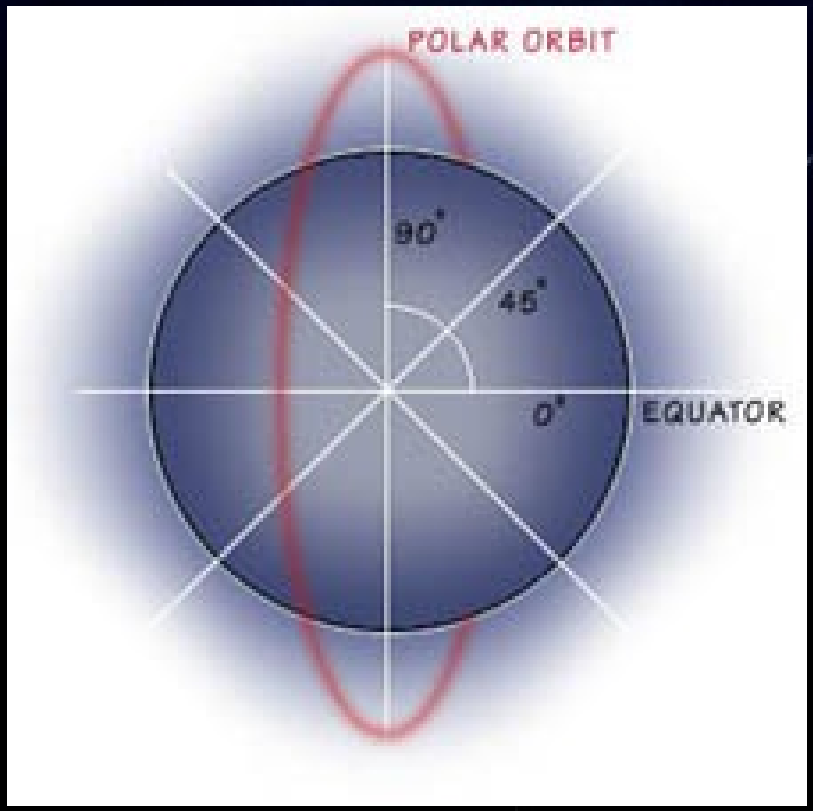
# *LEO Characteristics*

- Altitude:  about 500-1000 km
- Period:  about 101.5 minutes, 14 orbits/day
- Earth rotates 25.4 degrees for each satellite orbit, each pass is 25.4 degrees west of the last pass



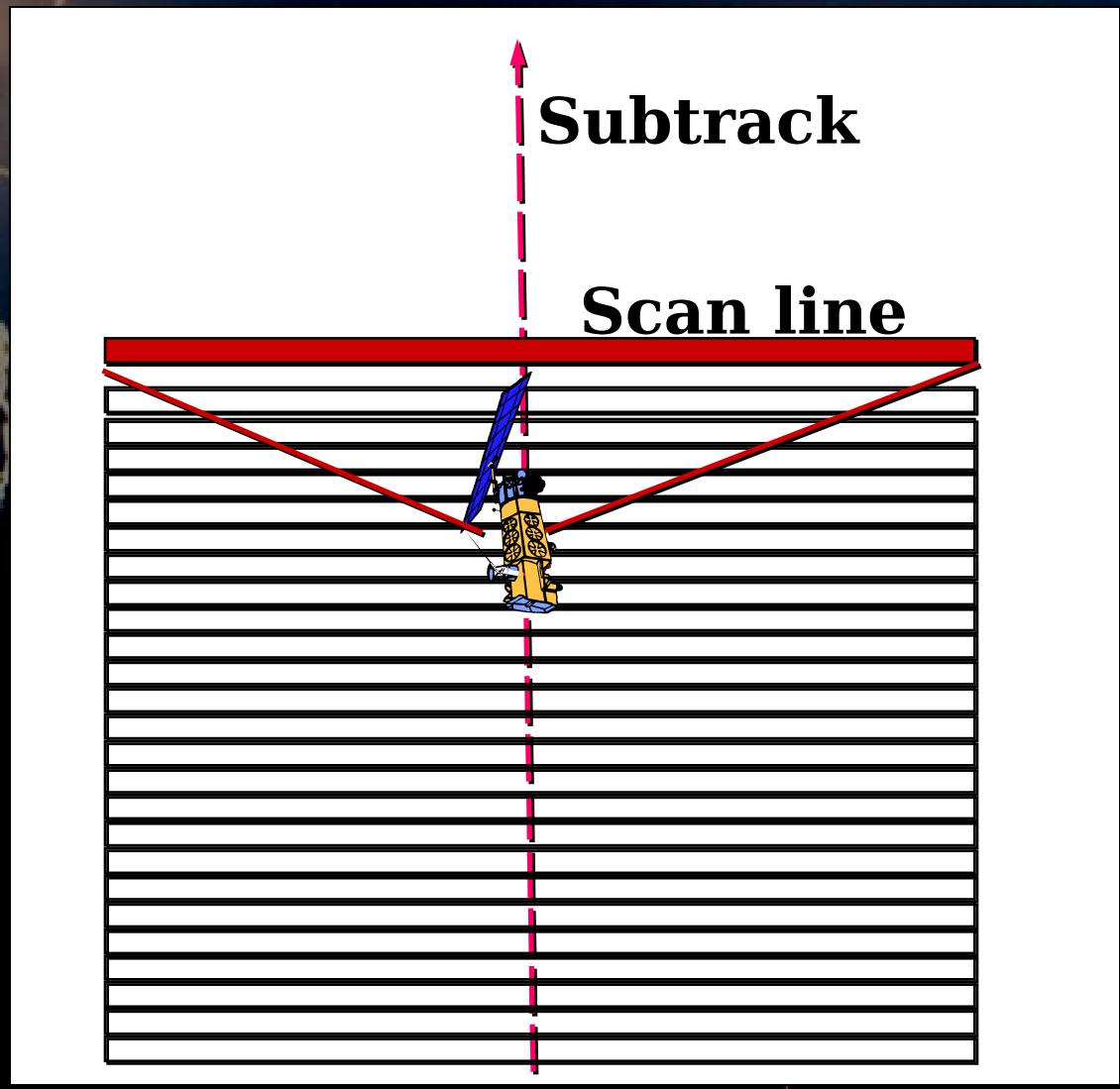
# *Orbital Features*

- Axis of orbit nearly perpendicular to earth's (inclination angle of 98 degrees)
- Satellites move across earth's surface moving S-N (ascending pass) or N-S (descending pass)
- Satellites come near both poles in each orbit



# LEO Scanning

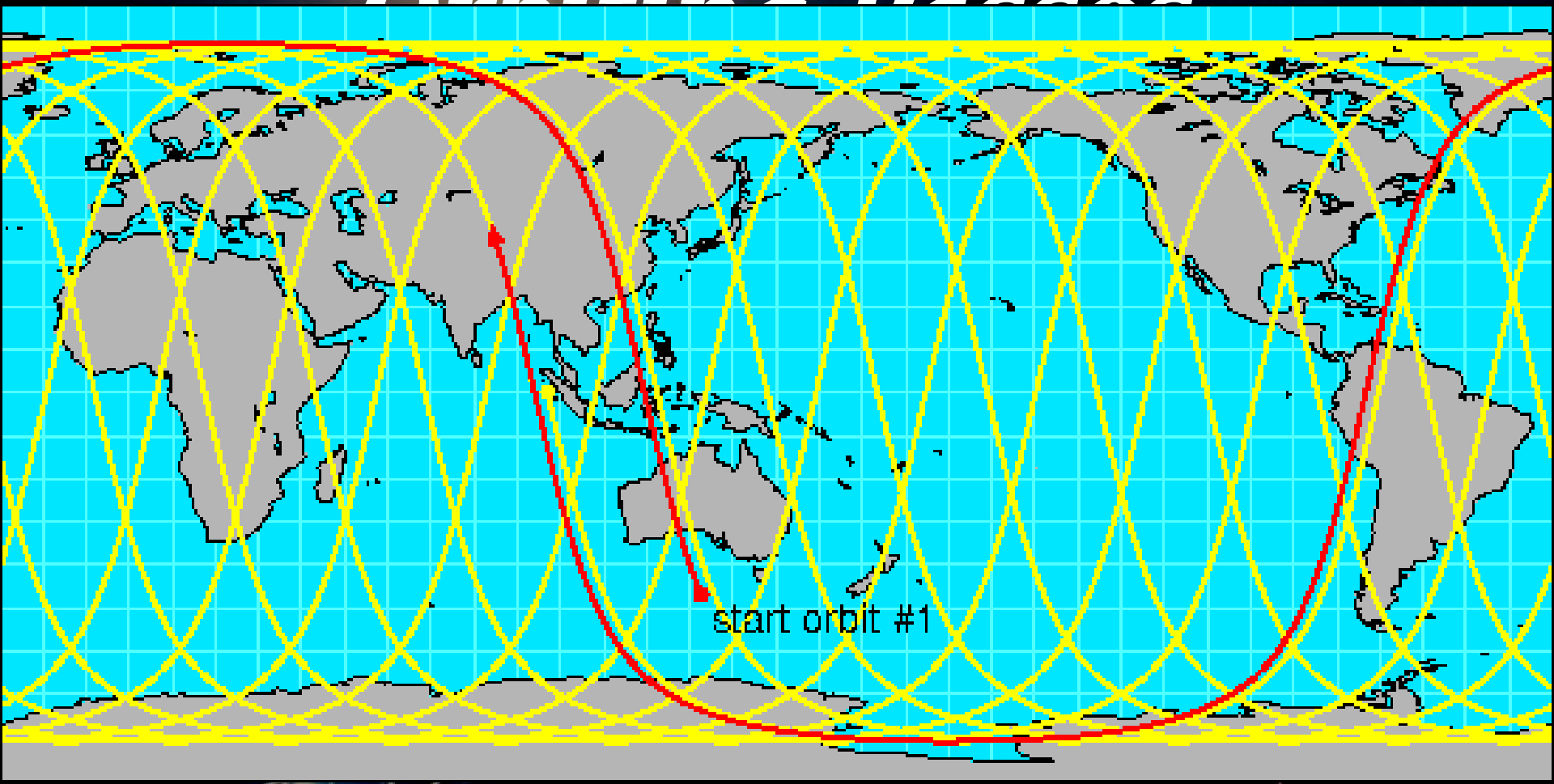
- Sensors record a scan line at a time
- "Passes" are created as these lines are pasted together



# *Direct Readout*

- Direct readout sites (most users) receive data scanned by satellite when it is being tracked (i.E. Above local horizon)
- Automated remote tracking stations/command readout sites can download data stored on satellite from earlier scans
- Command centers perform all functions: data download (current and stored), sensor calibration, orbital maintenance

# Ascending and Descending Polar Orbiting Passes

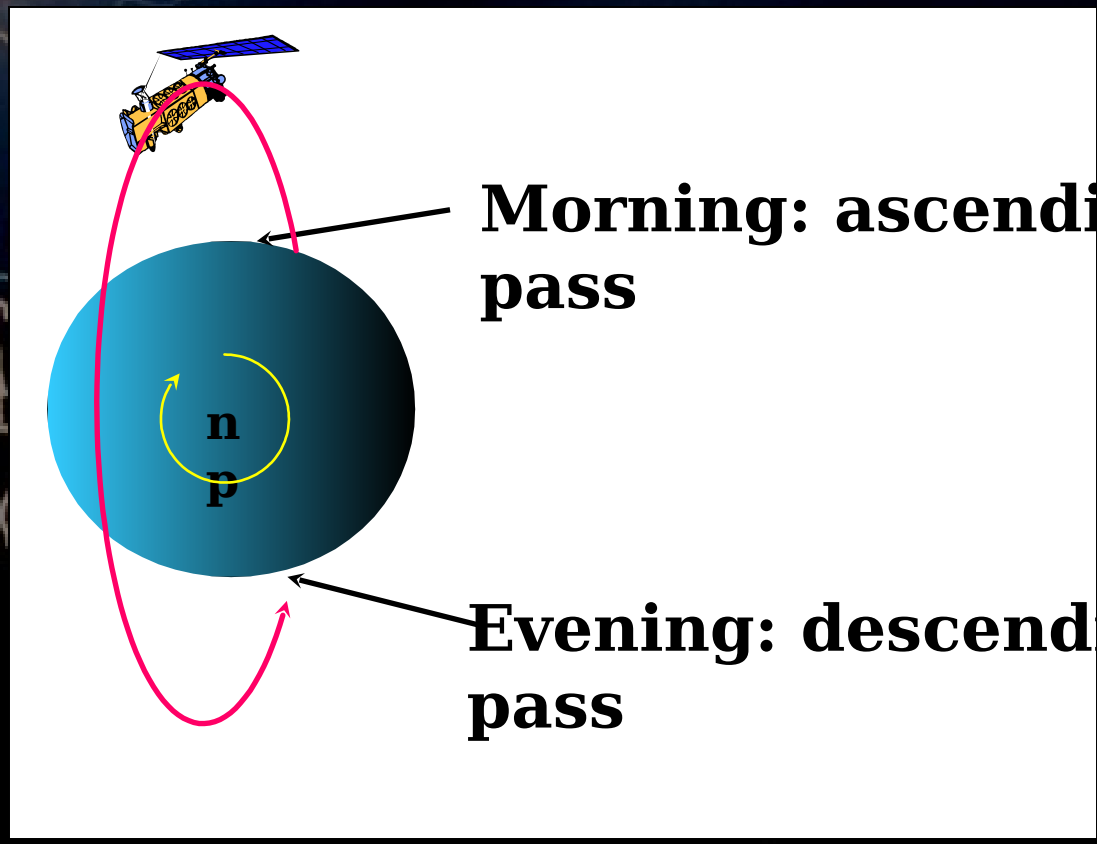


# *Polar Orbiting Satellites (POES)*

- Orbit features
- Scanning
- Direct readout
- Ascending and descending POES passes
- Operational polar orbiters

# POES Passes cont.

- Satellites pass over at about the same time every day.
- Sites get at least 2 passes a day: one ascending and one descending.



# *Operational Polar Orbiting Satellites*

- NOAA's Tiros
  - Advanced very high resolution radiometer (AVHRR)
  - Sounder
- Defense meteorological satellite program (DMSP)
  - Visual 0.5 km resolution
  - Special sensor microwave imager (SSM/I)

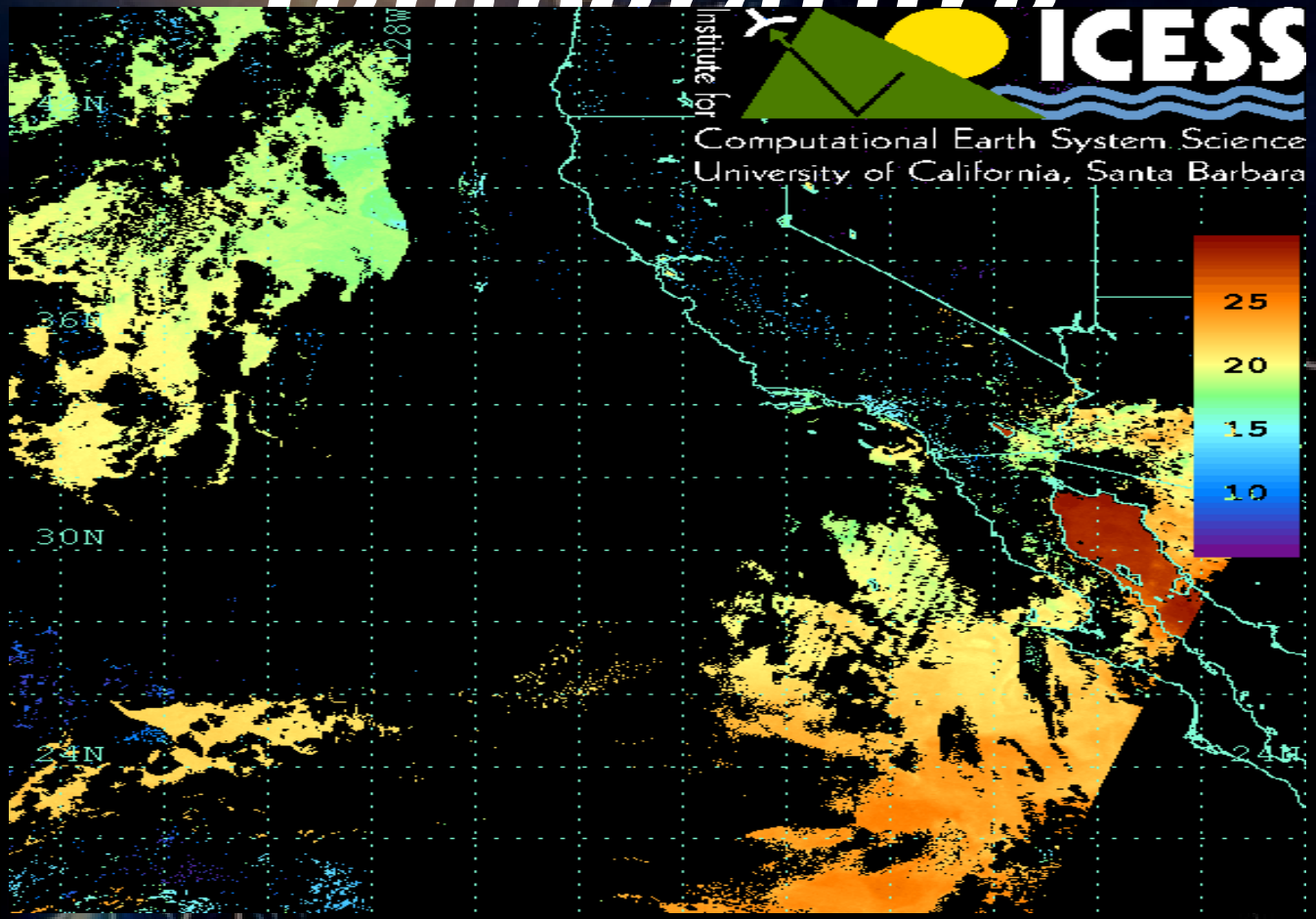
# NOAA 15/16 AVHRR/3 (imager)

- 1.1 km resolution at sub-point
- 5 channels
- 2048 pixels wide
- About 3000 km wide swath
- Applications include
  - Sea surface temperature
  - Ice/snow monitoring
  - Fire detection
  - Land use
  - Low cloud at night

# AVHRR Channels – Spectral Bands

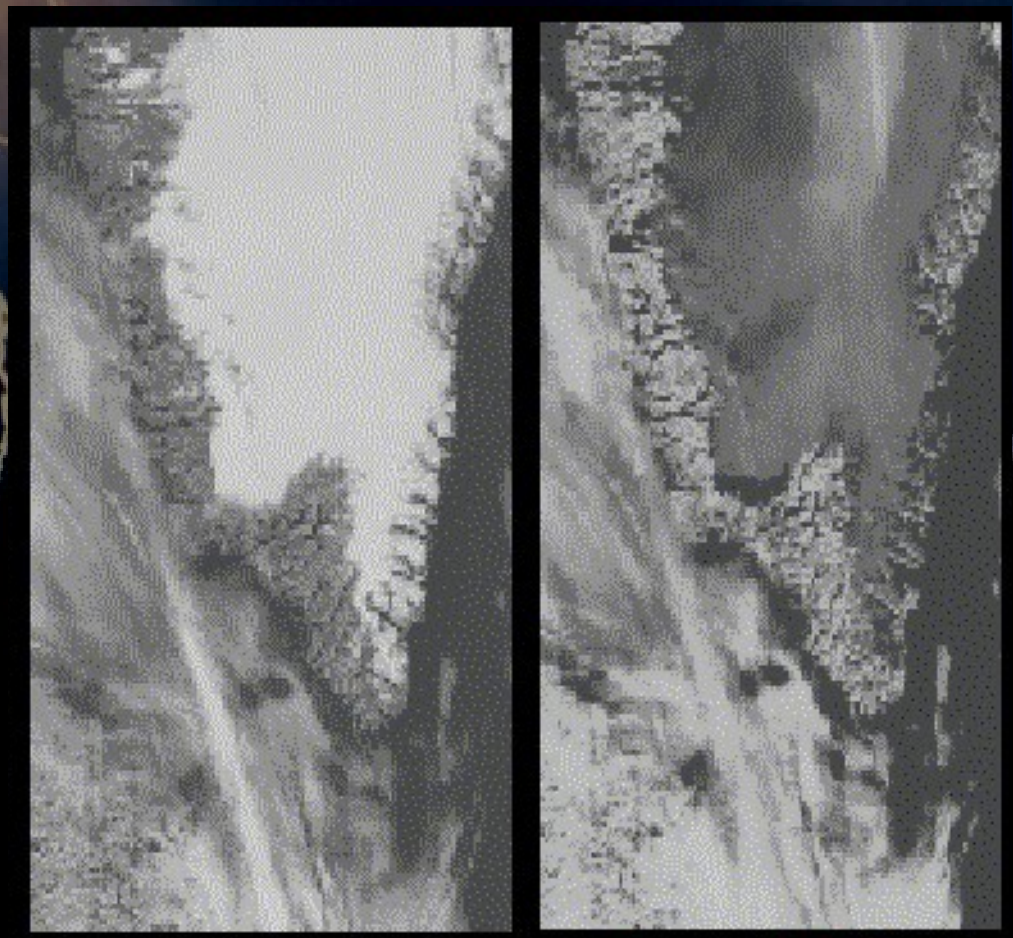
- Scanning radiometer
- 5 channels
  - Ch 1 0.6-0.7 µm Vis albedo/reflectance
  - Ch 2 0.7-1.1 µm NIR albedo/reflectance
  - CH 3a 1.58-1.64 µm NIR albedo/reflectance
  - Ch 3 3.5-3.9 µm NIR temperature
  - Ch 4 10.3-11.3 µm thermal IR temperature
  - Ch 5 11.5-12.5 µm thermal IR temperature

# NOAA AVHRR Sea Surface Temperature

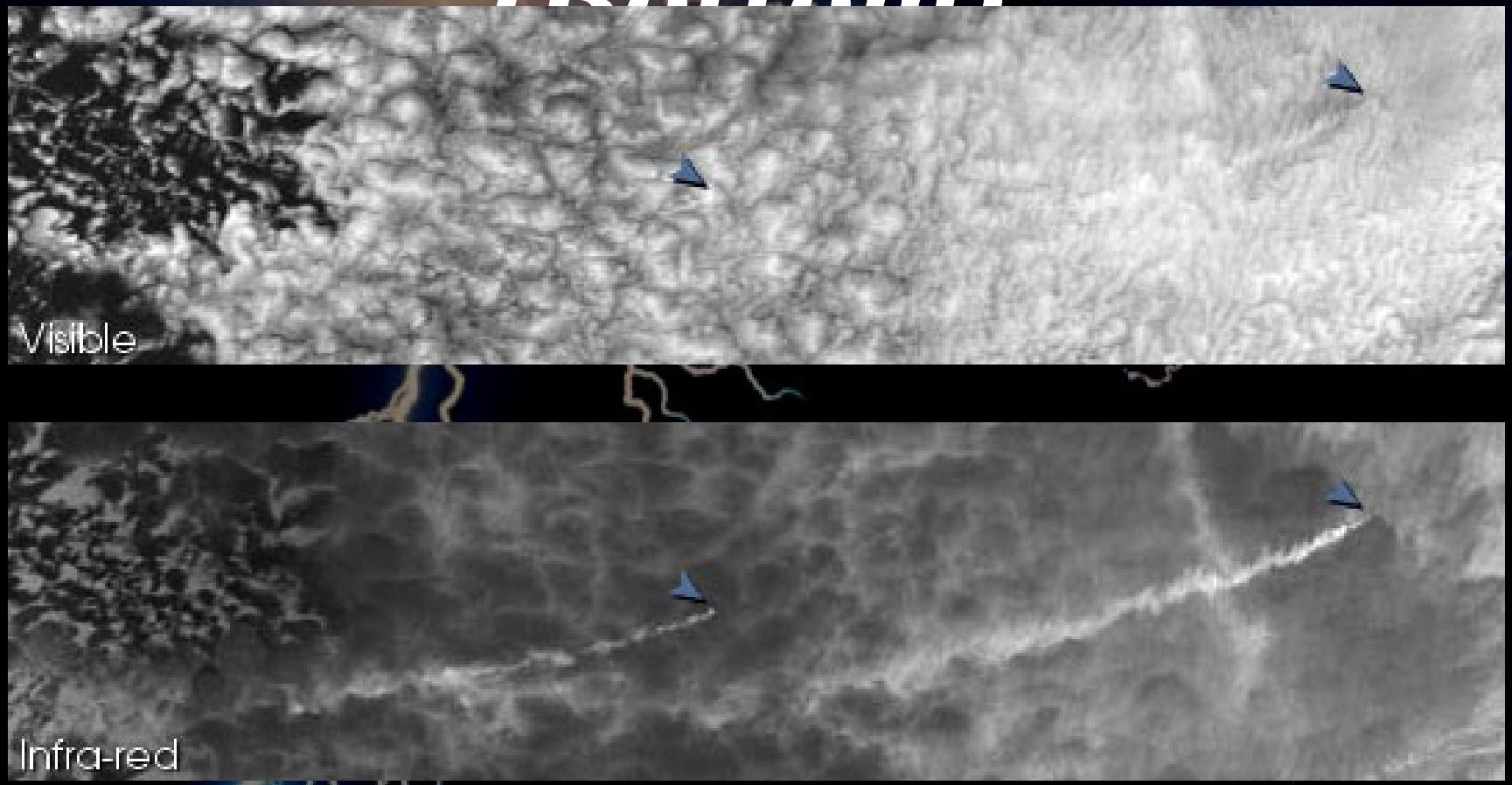


# *Channel 3a*

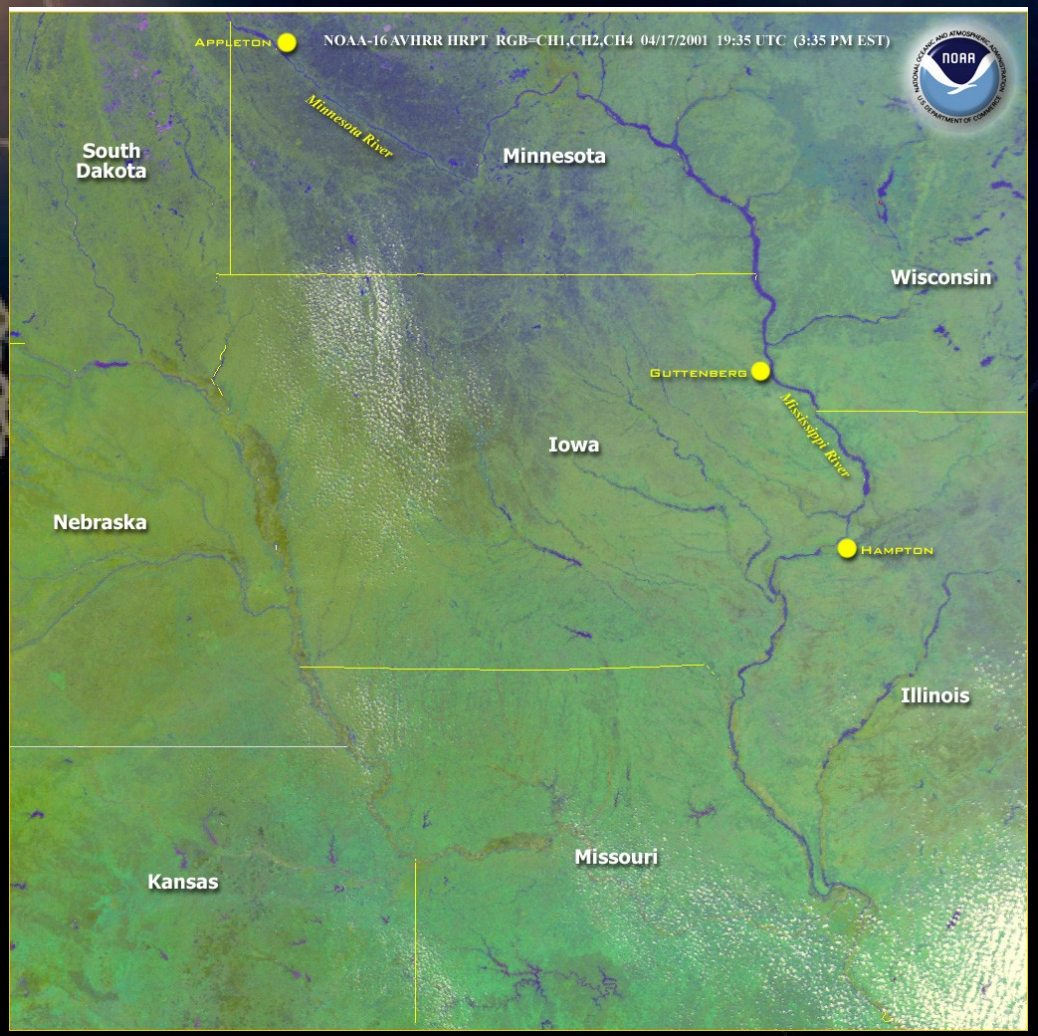
- 1.6 microns
- NIR
- Distinguishes clouds from snow and ice



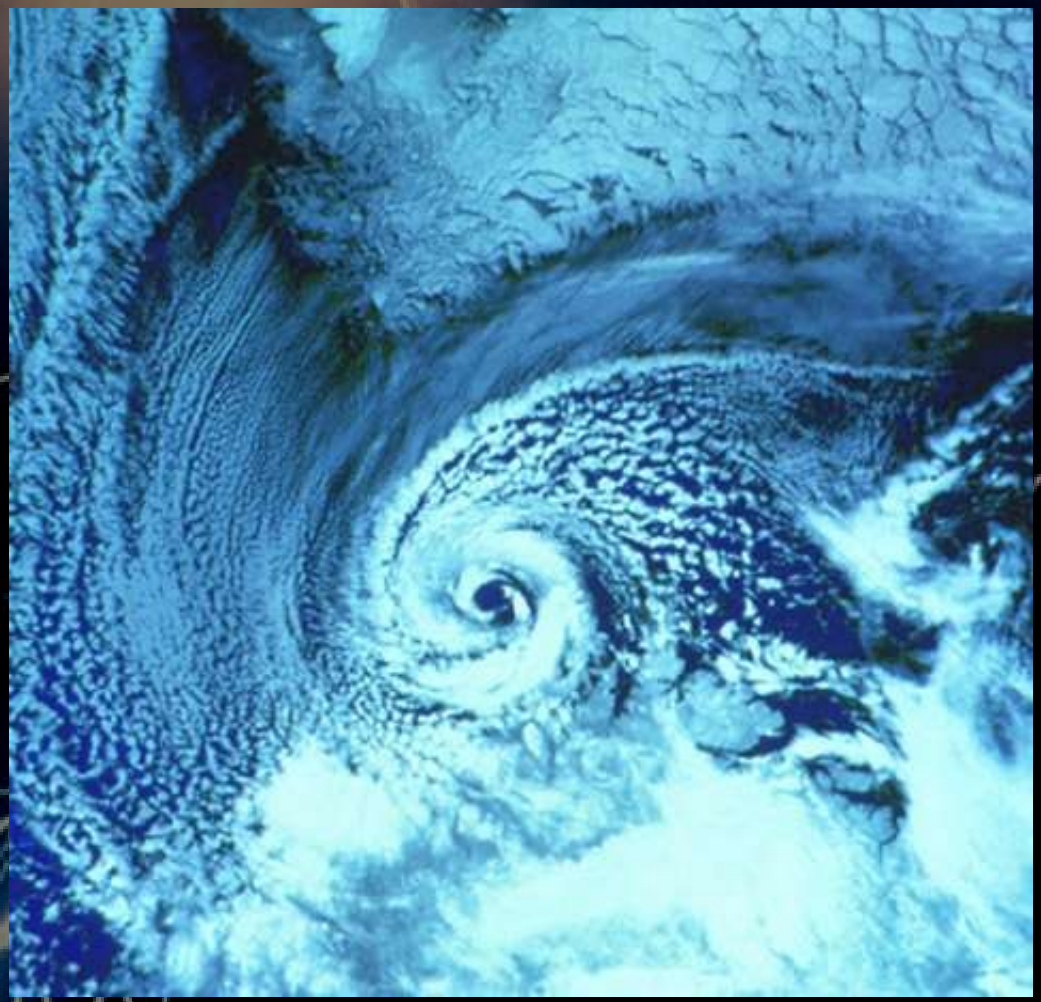
# Visible (Top) Shortwave Infrared (Bottom)



# Floodi ng

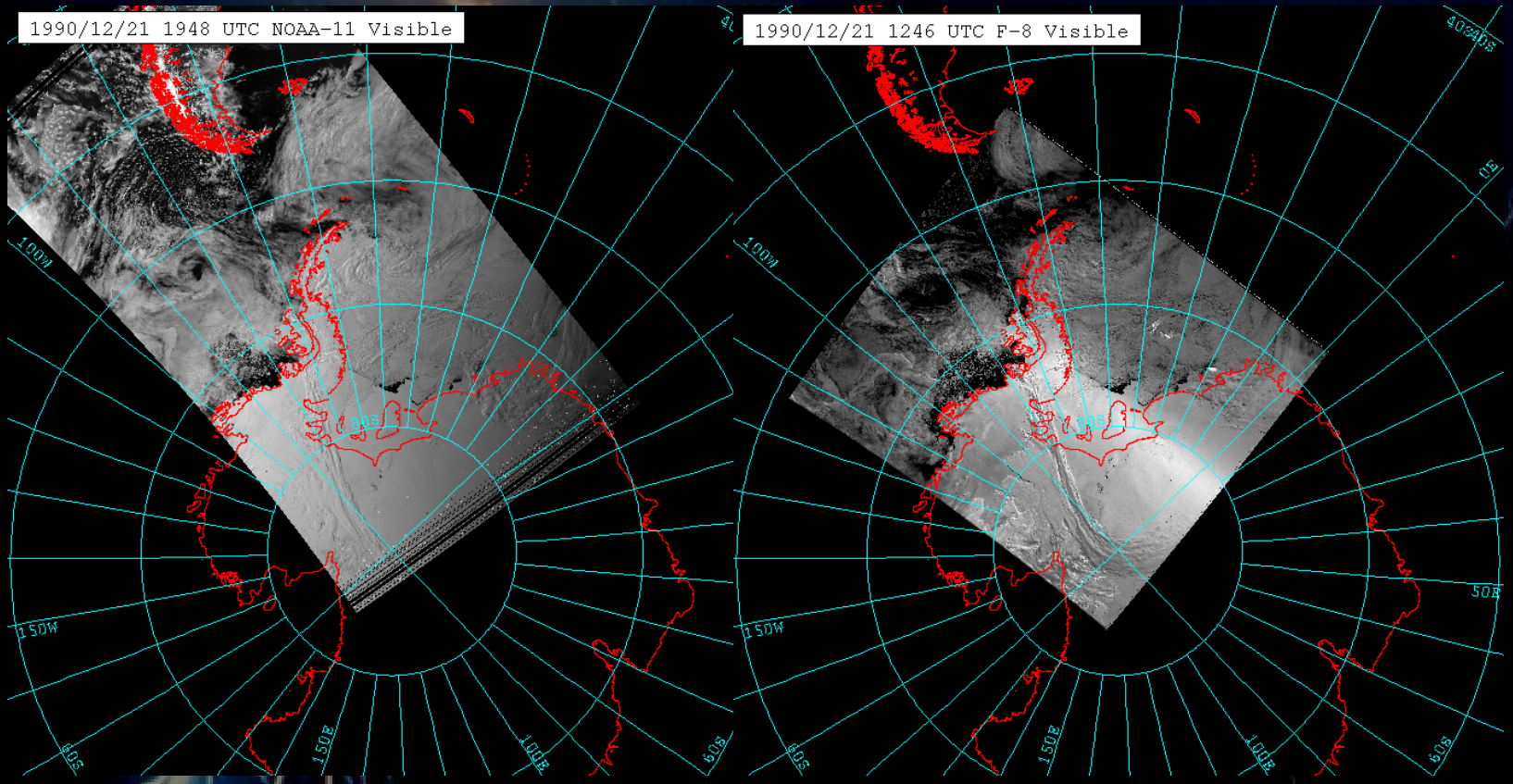

NOAA-16 AVHRR HRPT RGB=CH1,CH2,CH4 04/17/2001 19:35 UTC (3:35 PM EST)
NOAA
Appleton
Minnesota River
South Dakota
Minnesota
Wisconsin
Guttenberg
Mississippi River
Iowa
Nebraska
Hampton
Illinois
Missouri
Kansas

# *Polar Lows*



From: The National Snow and Ice Data Center (NSIDC)

# *LEO Views of Antarctica*



# *DMSP Satellites*

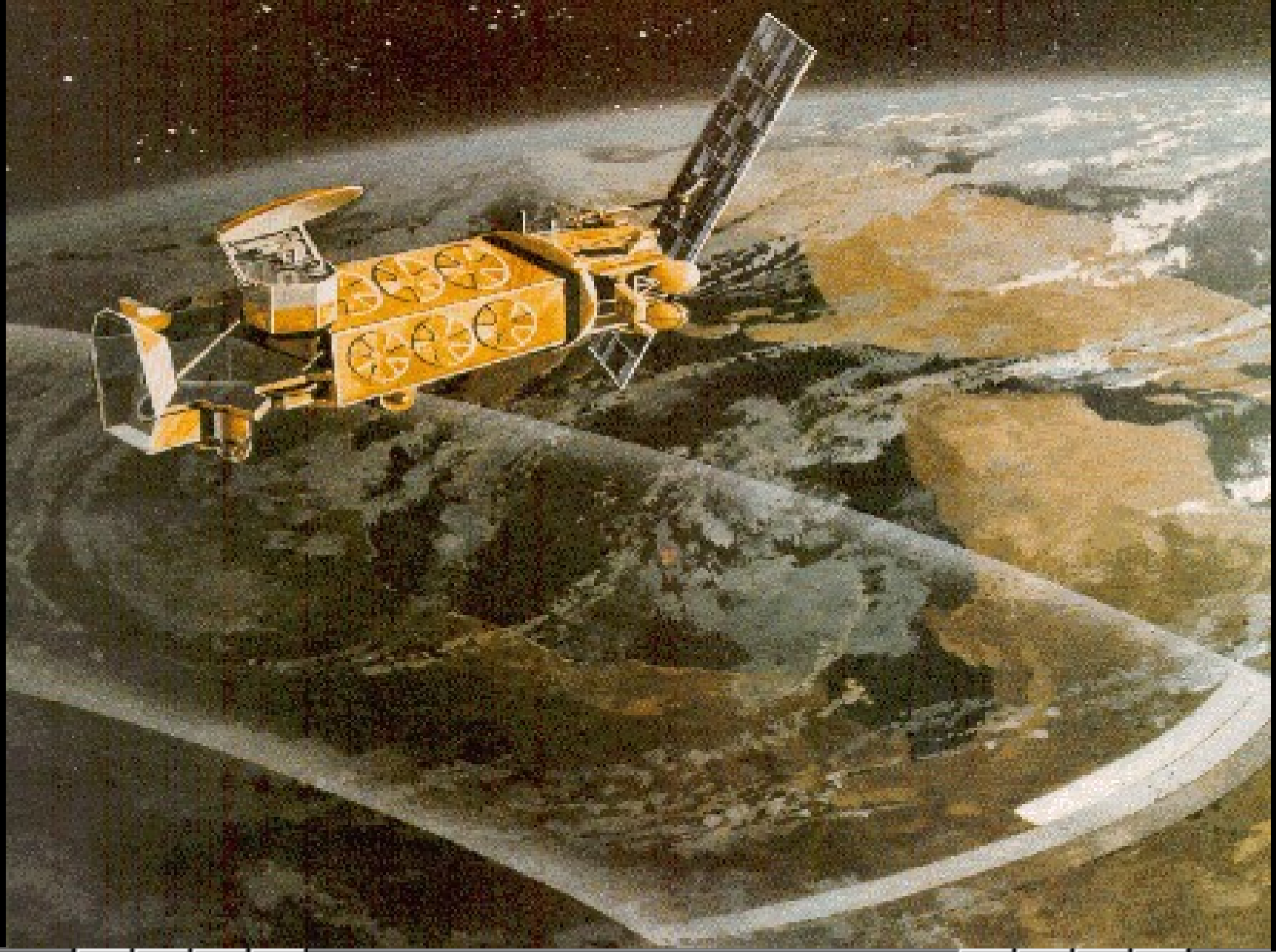
- Defense meteorological satellite program
- 4 meteorological sensors
  - OLS visible and infrared imager
  - SSM/I microwave imager
  - SSM/T1 temperature sounder
  - SSM/T2 water vapor sounder

# *OLS*

- Operational Linescan scanner
- Primary sensor on DMSP satellites
- 2 channel radiometer
  - Visible 0.4-1.1 µm
  - Infrared 10-12 µm

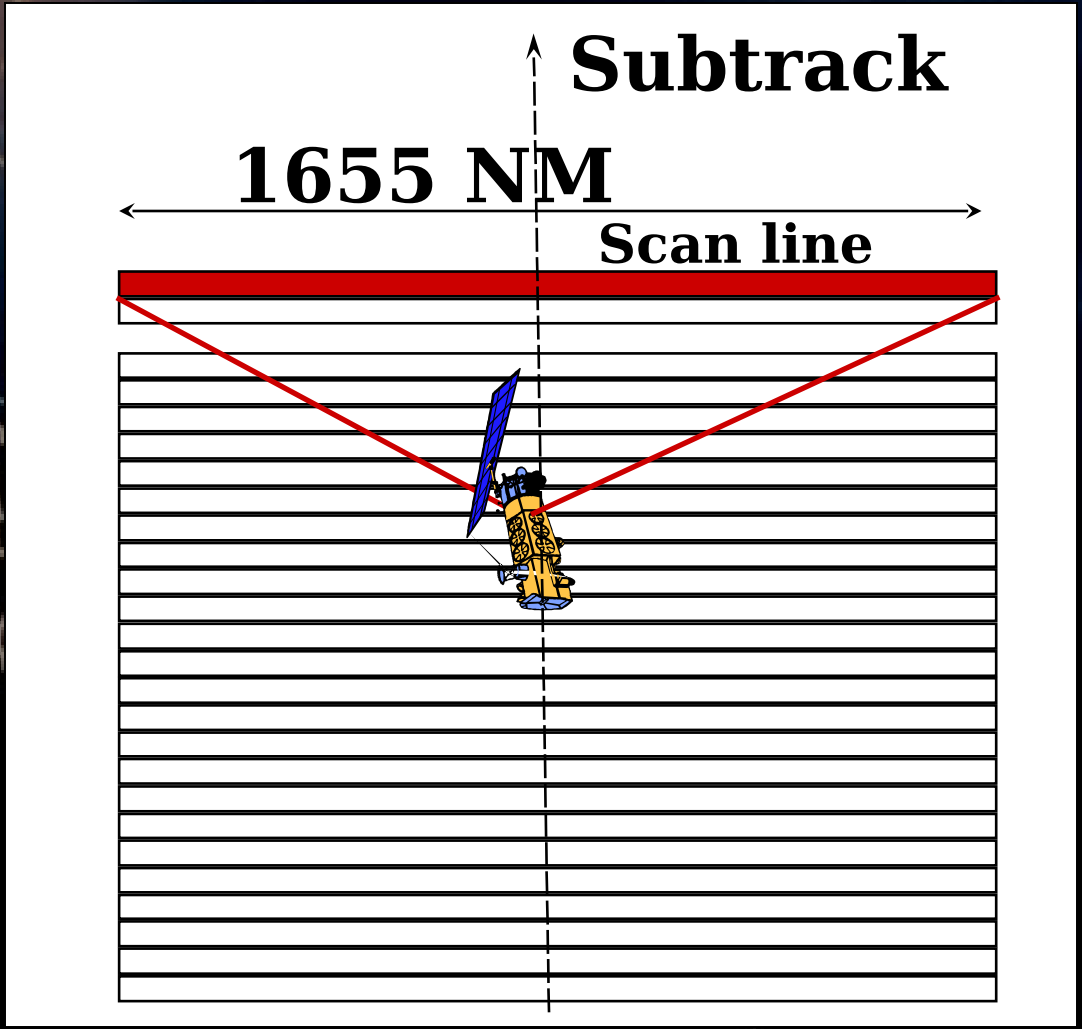
# *OLS continued*

- **Extremely high spatial resolution – 600 m**
- Radiometry is not as precise as AVHRR
- Designed to produce accurate and precise imagery, rather than accurate radiometry



# DMSP Coverage

- Continuously scans a 1655 NM wide line across subtrack. As it moves, the lines make up the swath.
- For a microwave scanner, swath is half as wide (827 NM).



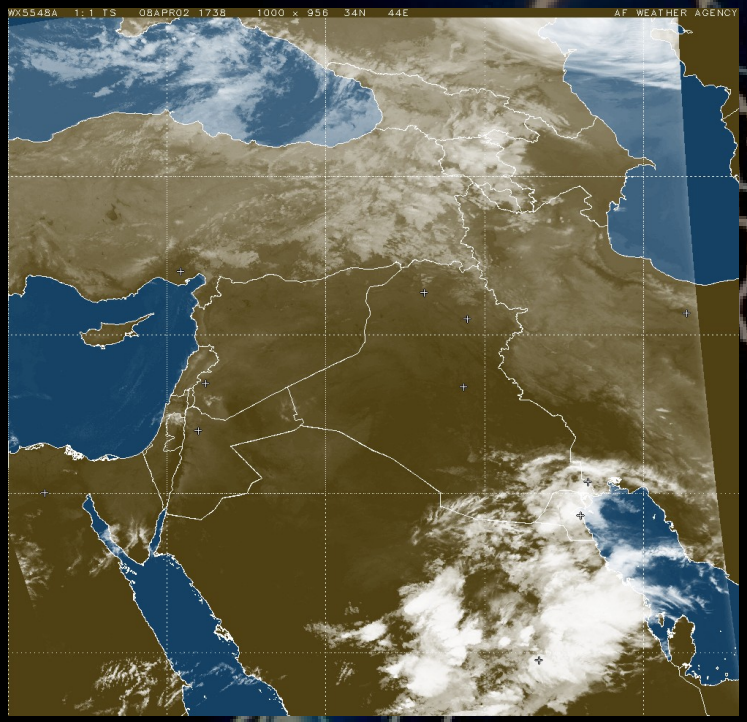
# Scanning – DMSP

- The DMSP has a similar scan to the NOAA except that the mirror is on a pendulum
- This gives two advantages:
  - It doesn't waste time looking into space, and can sweep slower
  - Pendulums slow down at the ends of their "swing," letting the sensor dwell there a little longer
- The result is better resolution that stays constant across the swath

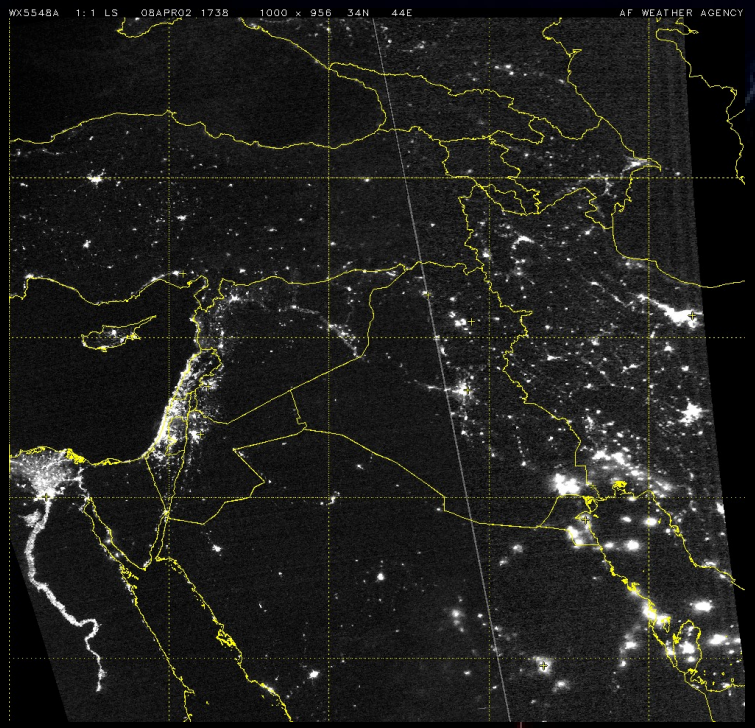
# *DMSP OLS*

- Nighttime IR Image and Nighttime Visible Image
- Lights can be seen in Nighttime Visible even through thin clouds

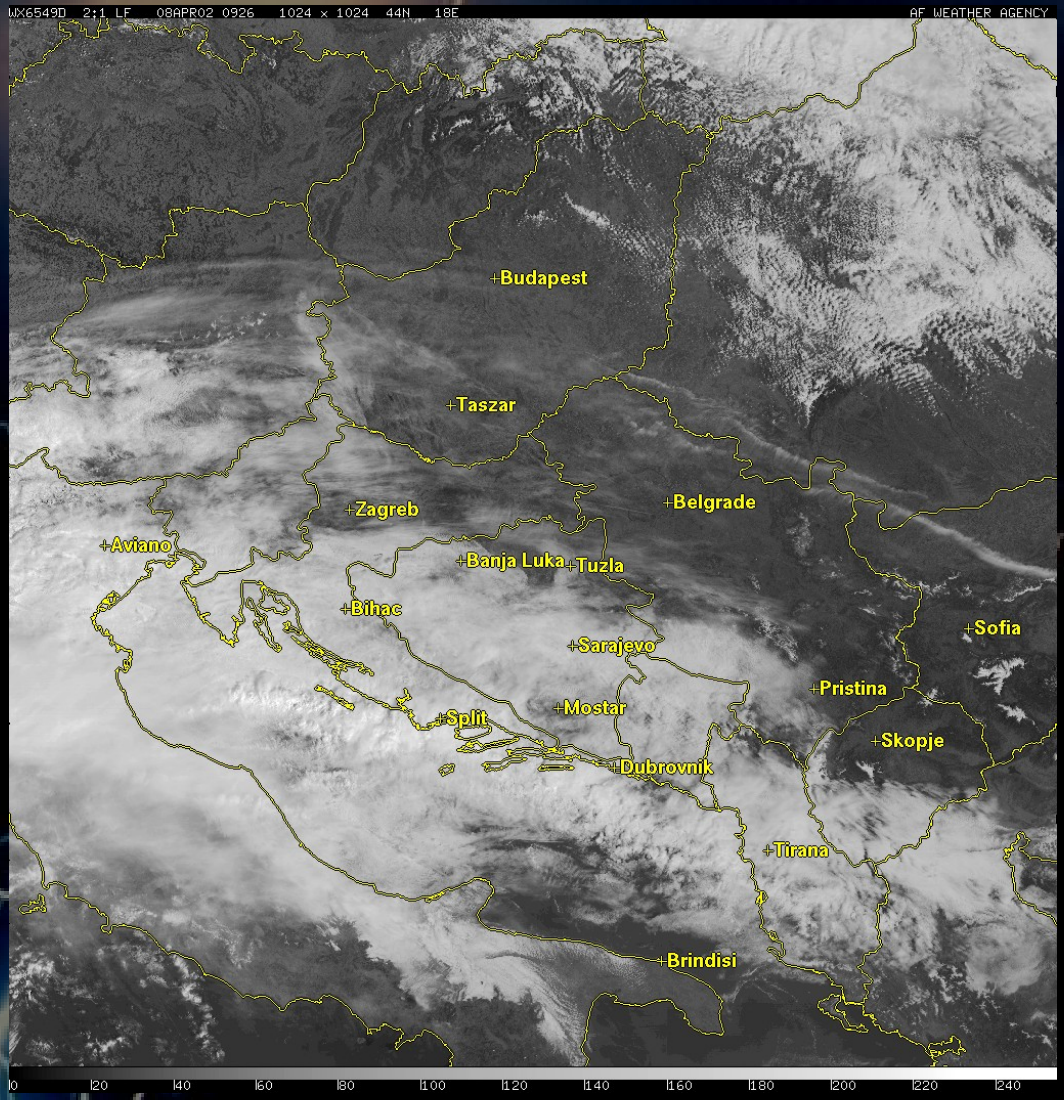
IR




Nighttime Visible



# DMSP OLS Visible Fine



# *"Research" Polar Orbiting Satellites*

- SeaWIFS
- MODIS
- TOMS

Pressed into operation by METOC by necessity!

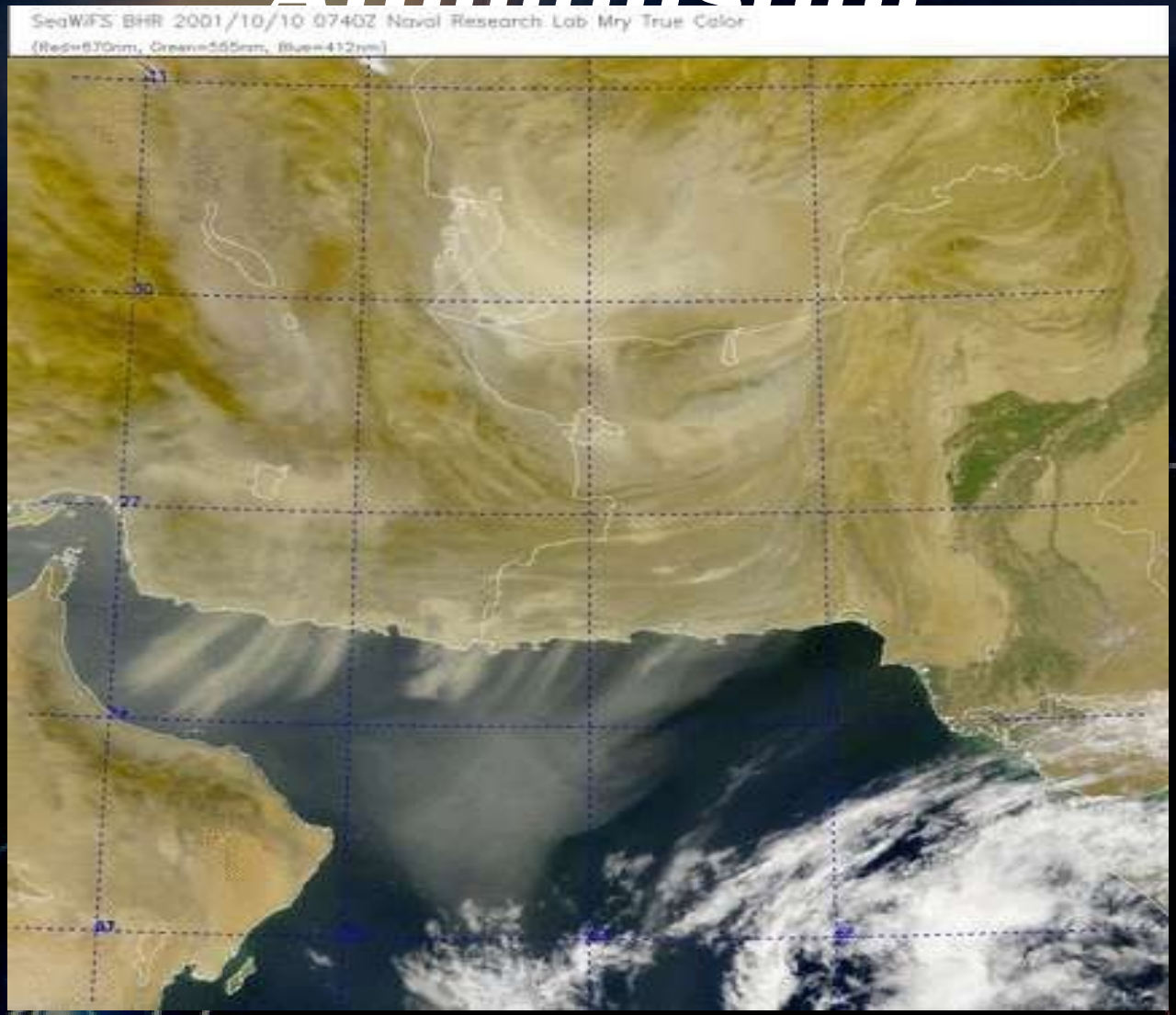
# *SeaWIFS*

Sea-Viewing Wide Field-of view Sensor

# *SeaWIFS Satellite*

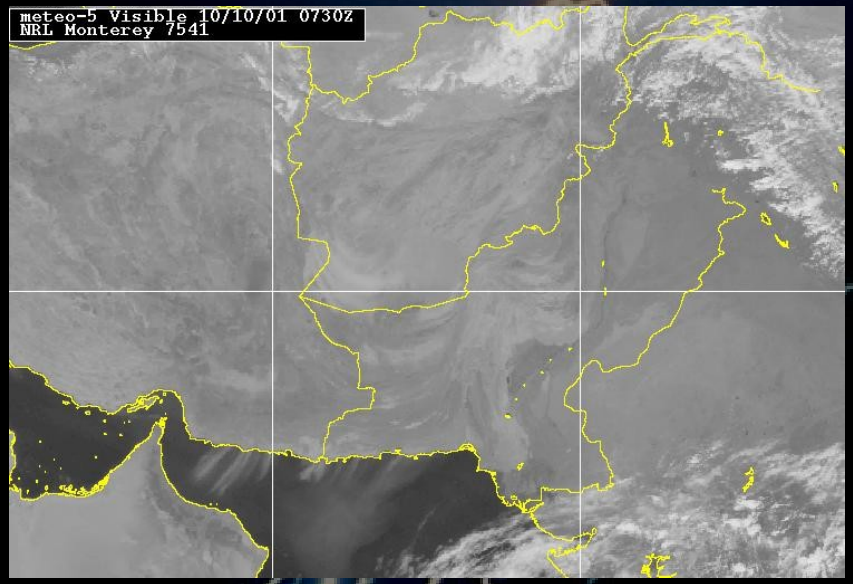
- SeaWIFS is privately-owned
- Navy has the right to data
- designed as an ocean-color satellite
  - detection of airborne dust

# SeaWIFS Image of Dust in Afghanistan

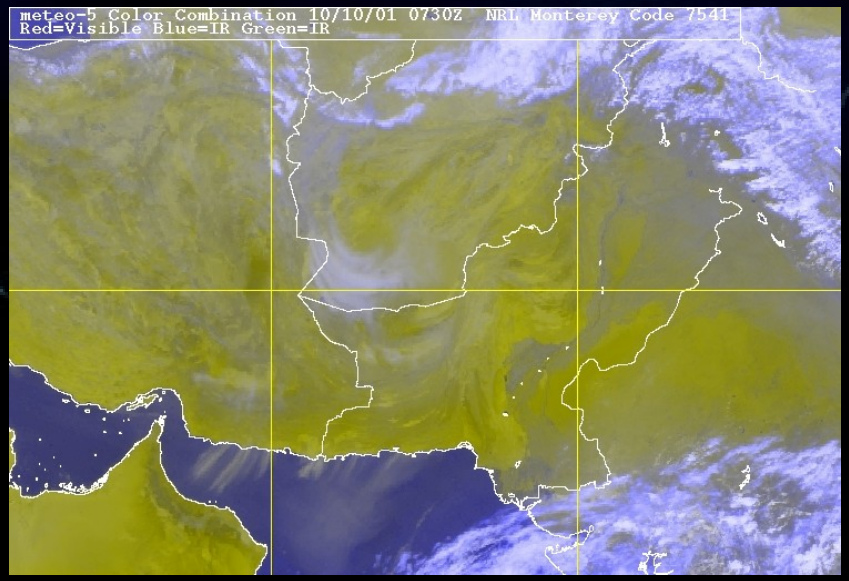


# Comparison of Afghanistan SeaWIFS Image to Meteosat

Meteosat Visible




Meteosat True Color

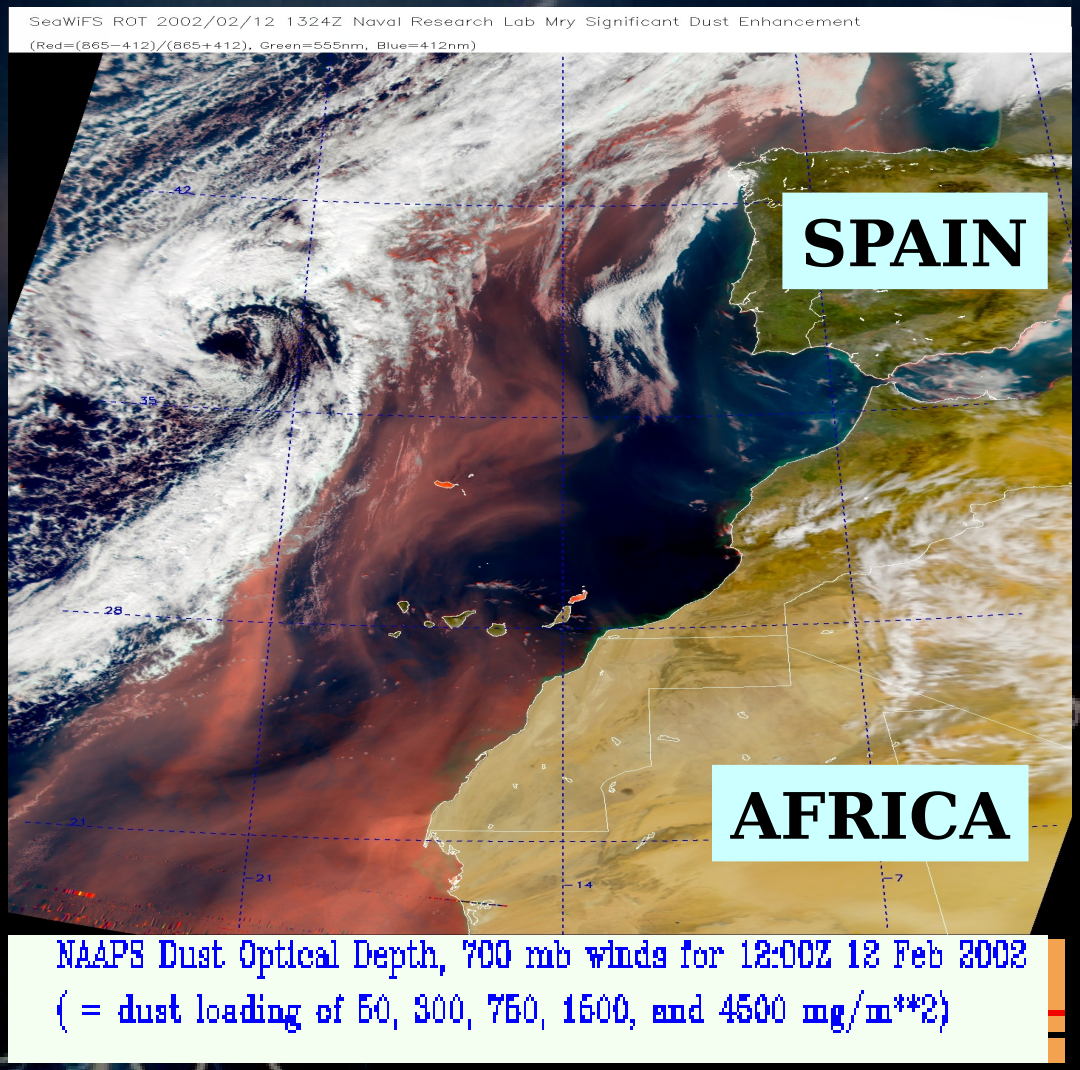


# Meteosat Animation of Afghan Dust

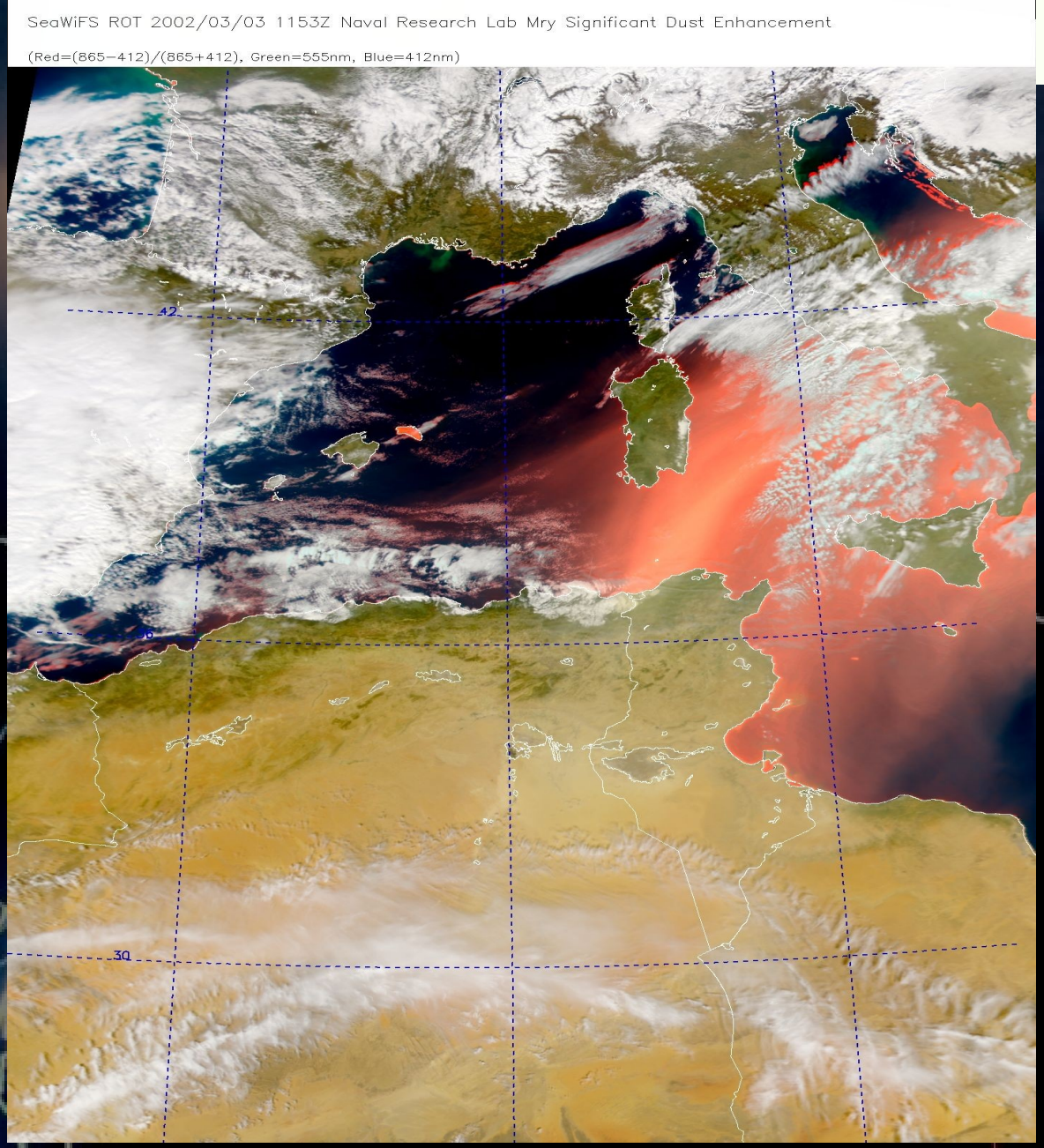
# SeaWIFS Channels

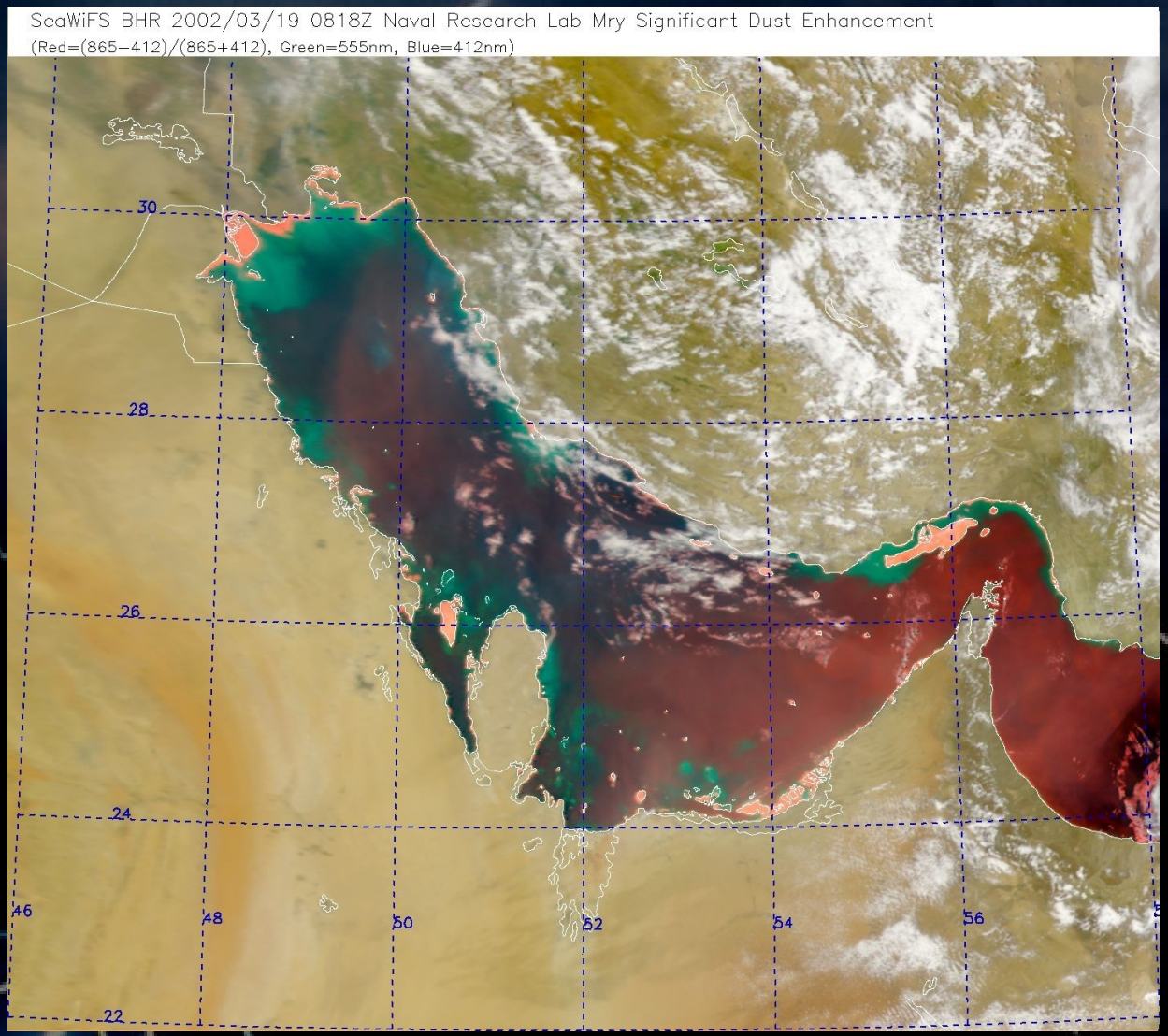
- 1) 402-422 nm
- 2) 433-453 nm
- 3) 480-500 nm
- 4) 500-520 nm
- 5) 545-565 nm
- 6) 660-680 nm
- 7) 745-785 nm
- 8) 845-885 nm

1000 nm = 1μm
So 500 nm = 0.5 μm


SeaWiFS ROT 2002/02/12 1324Z Naval Research Lab Mry Significant Dust Enhancement
(Red=(865-412)/(865+412), Green=555nm, Blue=412nm)
SPAIN
AFRICA
NAAPS Dust Optical Depth, 700 mb winds for 12:00Z 13 Feb 2002
( = dust loading of 50, 300, 750, 1600, and 4500 mg/m**2)

First image shows NAAPS Optical Depth and Winds
Second image shows SeaWIFS Dust


SeaWiFS ROT 2002/03/03 1153Z Naval Research Lab Mry Significant Dust Enhancement
(Red=(865−412)/(865+412), Green=555nm, Blue=412nm)
2002
42
30


SeaWiFS BHR 2002/03/19 0818Z Naval Research Lab Mry Significant Dust Enhancement
(Red=(865−412)/(865+412), Green=555nm, Blue=412nm)
30
28
26
24
22
46
48
50
52
54
56

# Imaging Spectroradiometer (MODIS)

- Not originally intended as an operational satellite, it's an instrument on NASA's "global change" (climate) satellite, known as EOS (Earth Observation System)
- Large number of METOC applications
- 36 Raw Spectral Channels (too many to know by METOC personnel)
- Three Different Spatial Resolutions

# *Imaging Spectroradiometer (MODIS)*

- Low Earth Orbiting (Sun-synchronous)
- Satellite names: Aqua and Terra
- Many more instruments than just MODIS aboard

# *MODIS Channels*

1-2 Land/Sea Boundaries

3-7 Land/Cloud Properties

8-16 Ocean Color/Phytoplankton/ Biogeochemistry

17-19 Atmospheric Water Vapor

20-23 Surface/Cloud Temperatures

24-25 Atmospheric Temperature

26 Cirrus

27-29 Water Vapor

30 Ozone

31-32 Surface/Cloud Temperature

33-36 Cloud Top Altitude

# *MODIS Spatial Resolution*

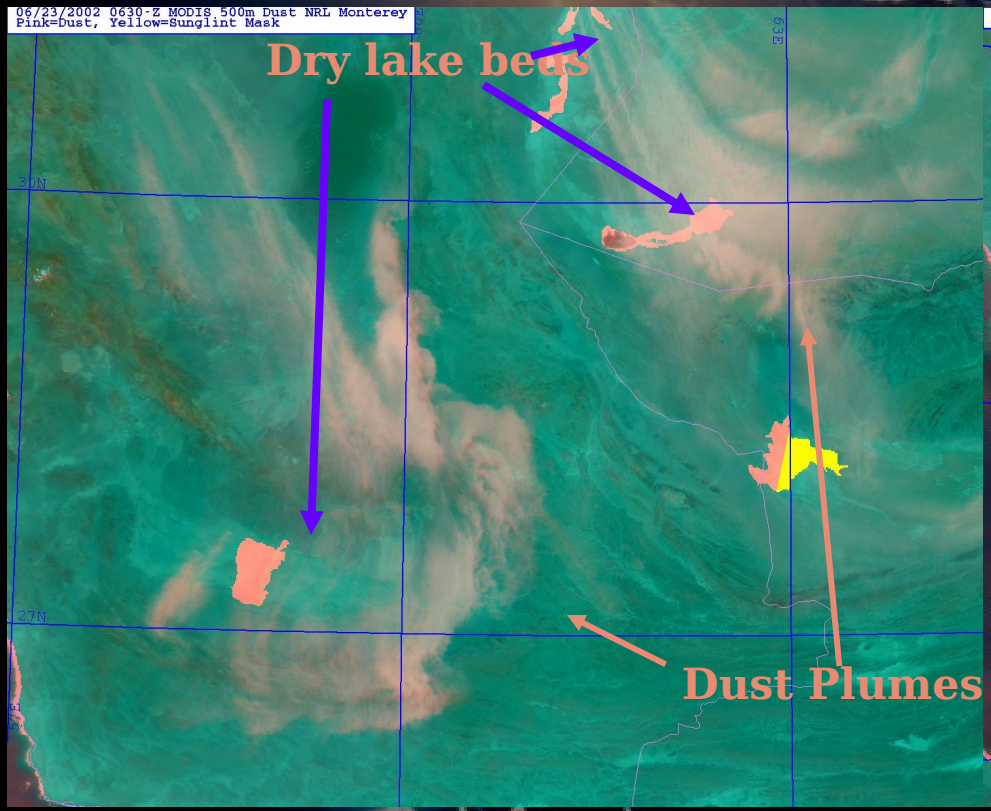
- Channels 1 & 2 Daytime Only
  250 m
- Channels 3 – 7 Daytime Only
  500 m
- Channels 8 – 36
  1000 m

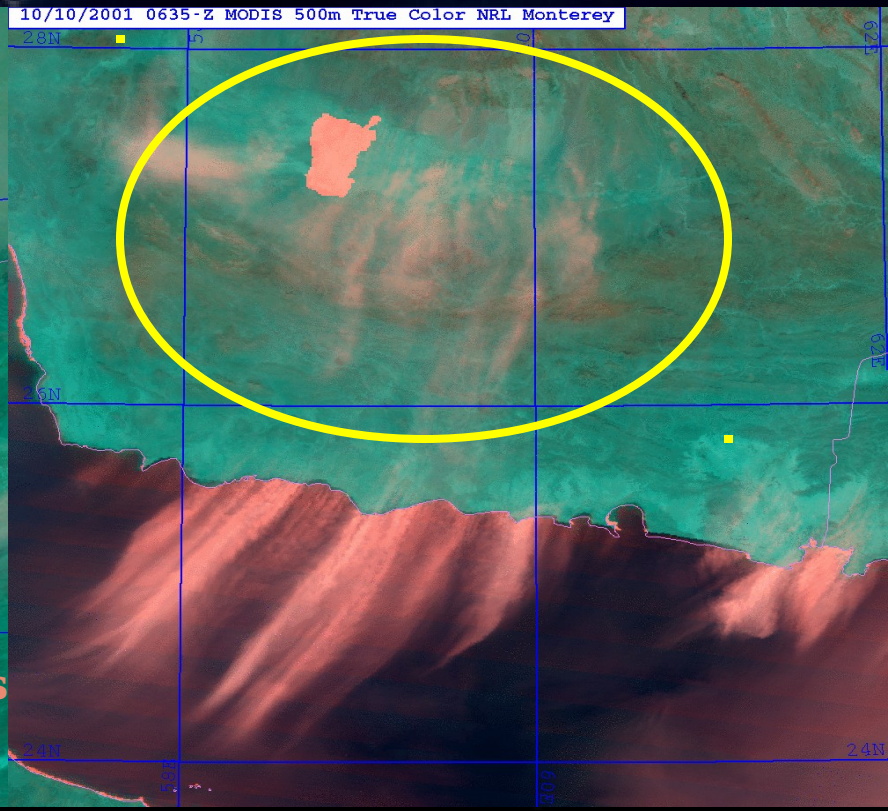
Bottom Line: Spectacular SuperHi-Resolution Shots available but daytime only!

# *MODIS Applications for METOC*

- Dust (includes land) – GREAT PRODUCT!
- Low Cloud at Night – Improved!
- Water Vapor – High Resolution
- Smoke and Fires
- Land Properties
- Cloud and Surface Properties
- Contrails

# Dust Enhancements Over Water and Land Surfaces

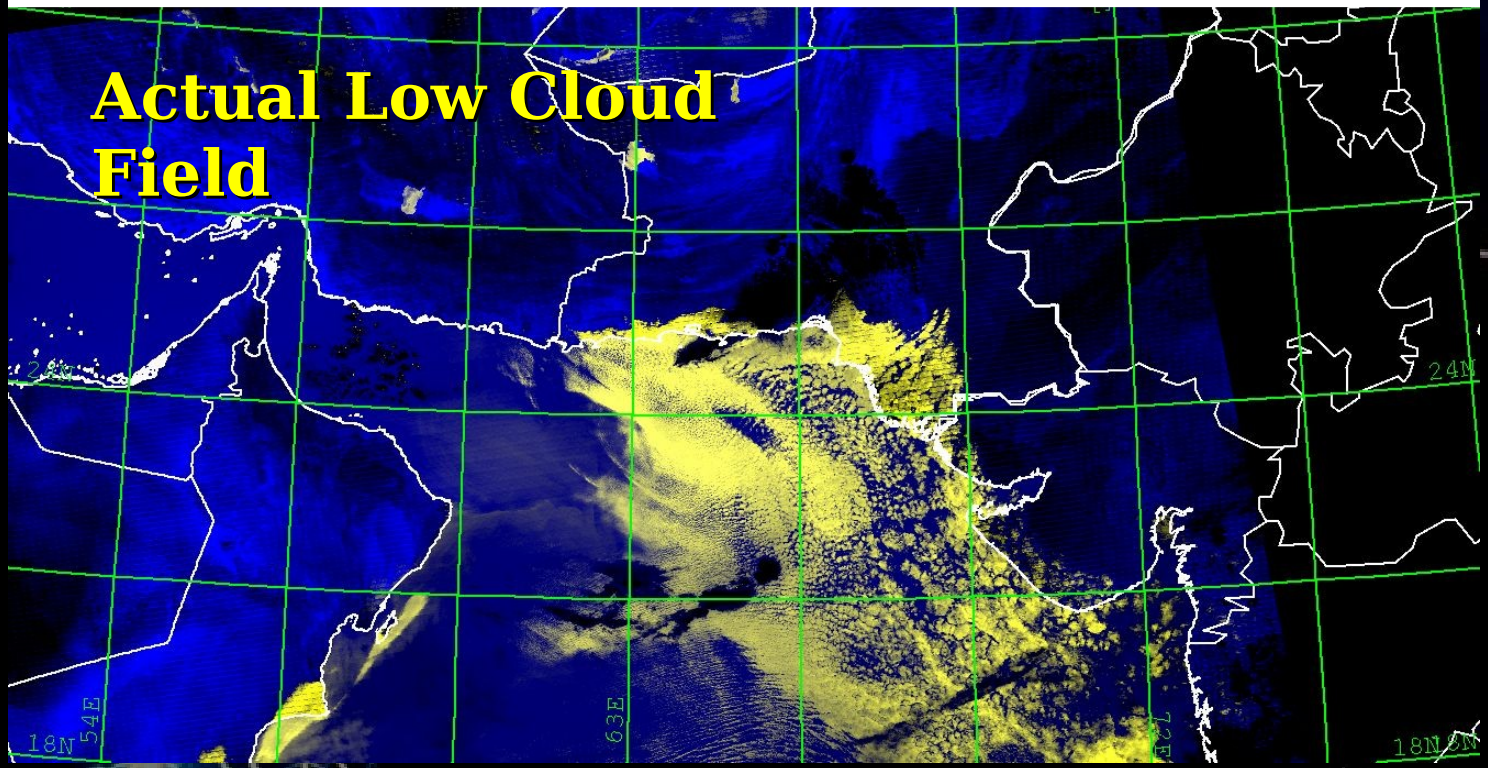



Multi-spectral algorithm enhances dust over both land and ocean backgrounds. Dry lake beds can act as sources of dust.

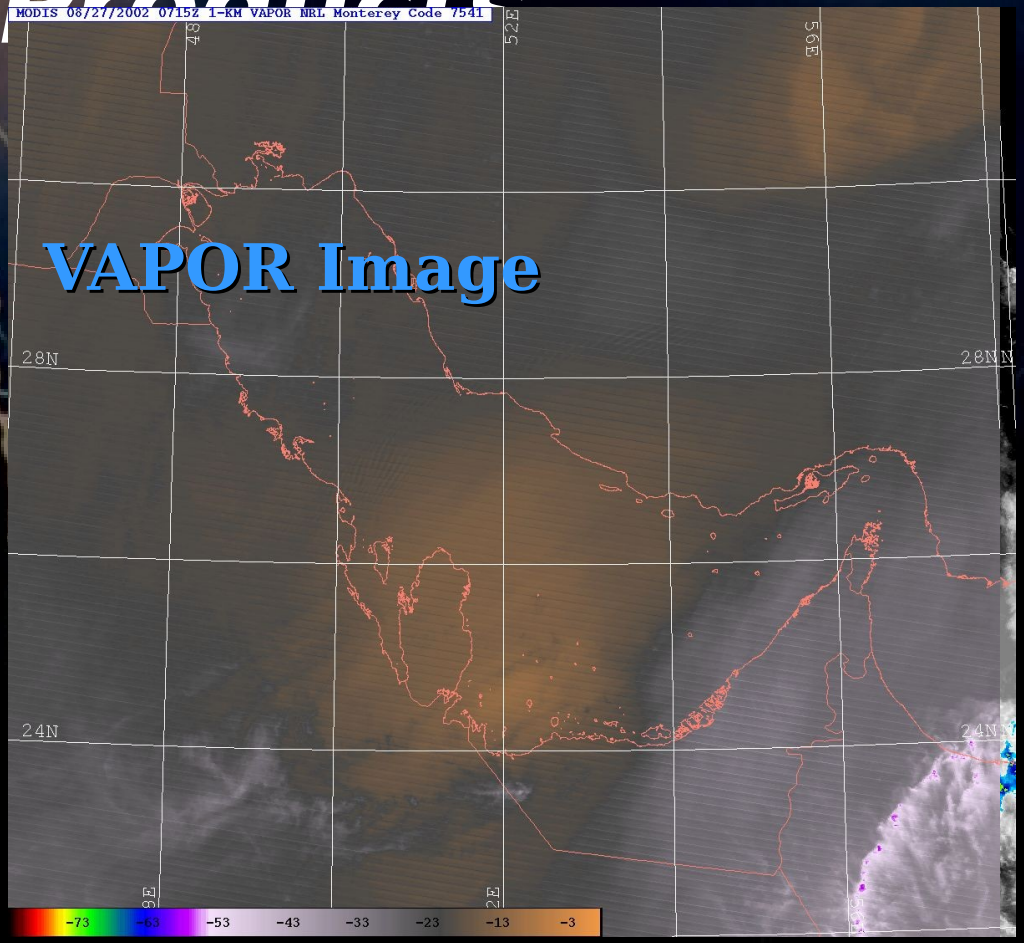
# Nocturnal Low Clouds

MODIS channels near 4.0μm provide the unique capability to distinguish low cloud from high 4.0μm reflecting desert surfaces, thereby eliminating false positives to a large extent.



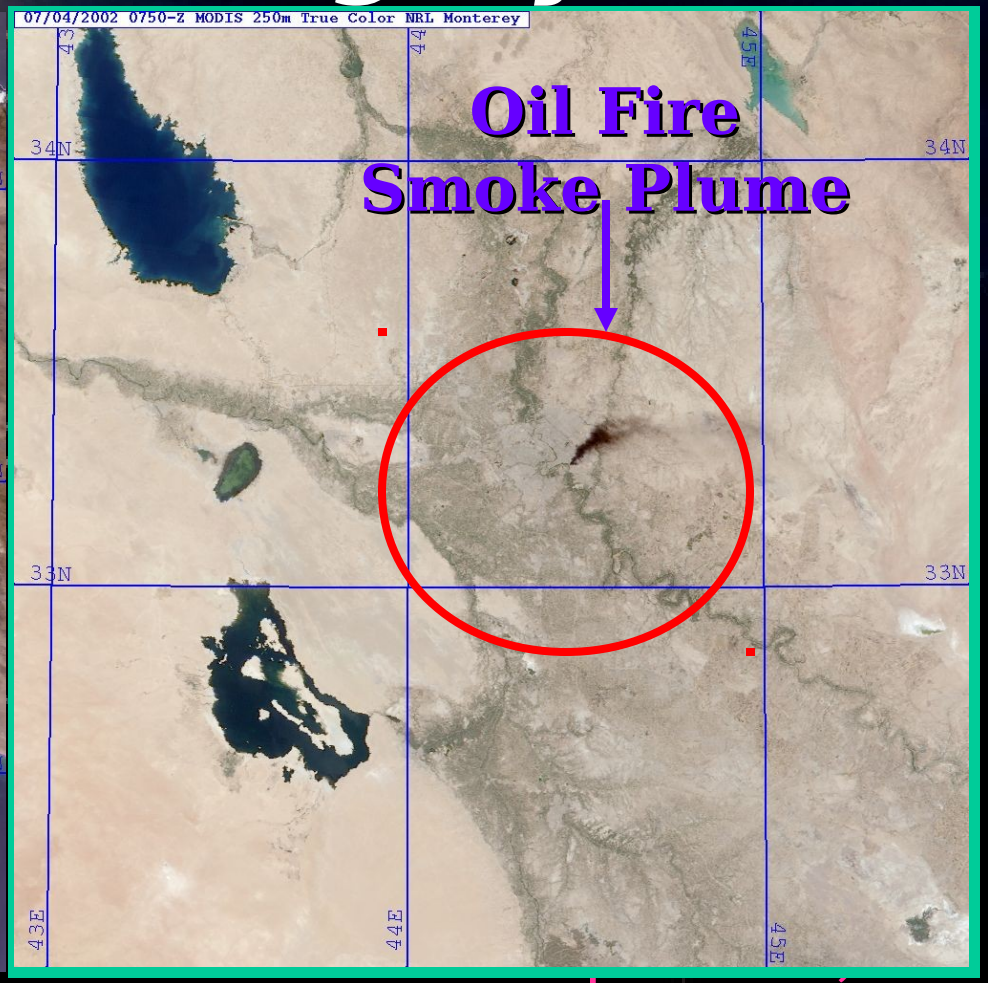
# VIS/IR/VAPOR Products

- MODIS visible imagery available at spatial resolutions up to 250m.
- Infrared window (e.g., 11.0μm) data available at 1km resolution.
- MODIS water vapor channel reveals never-before observed mesoscale atmospheric circulations (useful, e.g., in identifying regions of possible CAT).

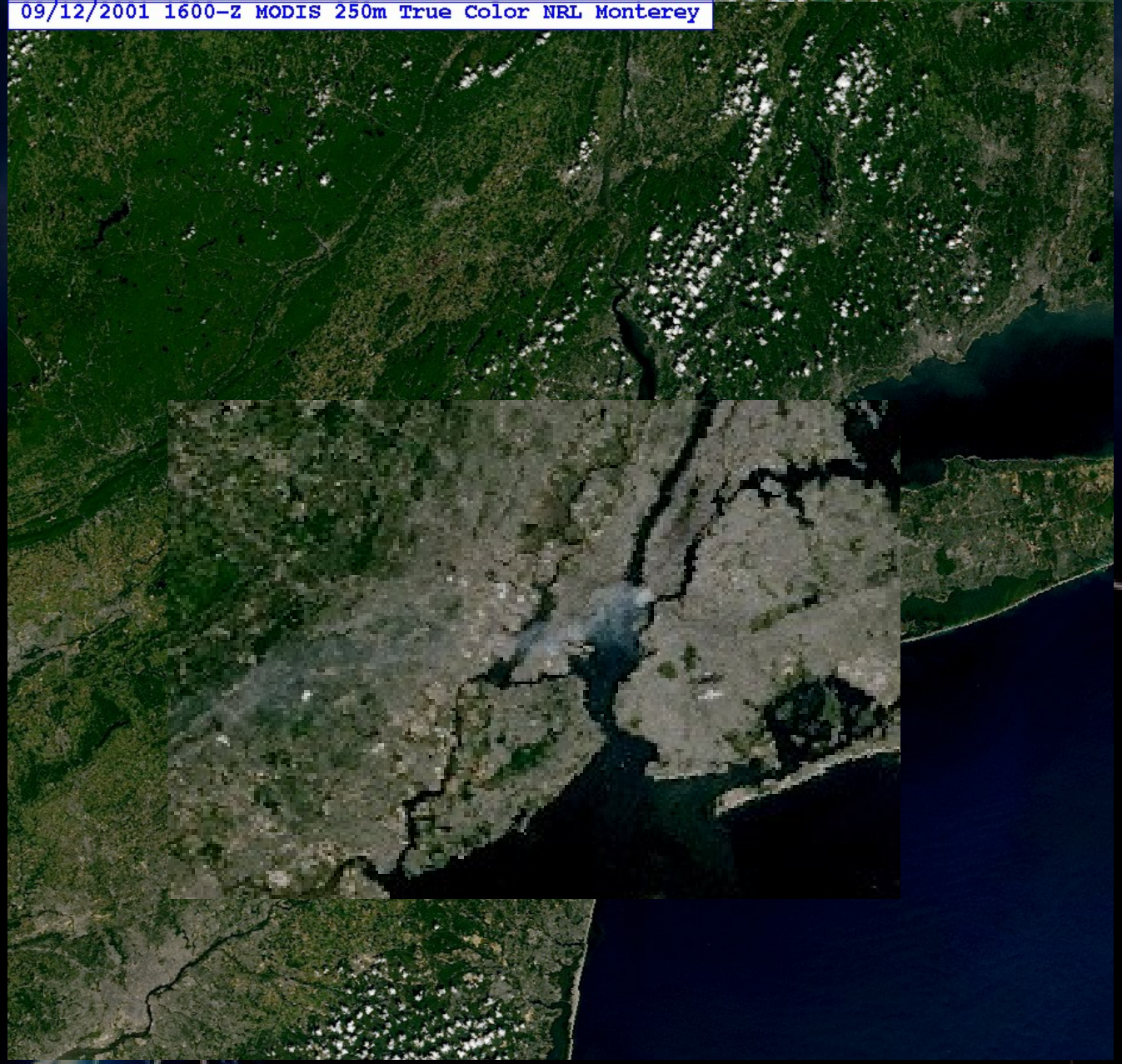


VAPOR Image

# High Resolution True Color Imagery

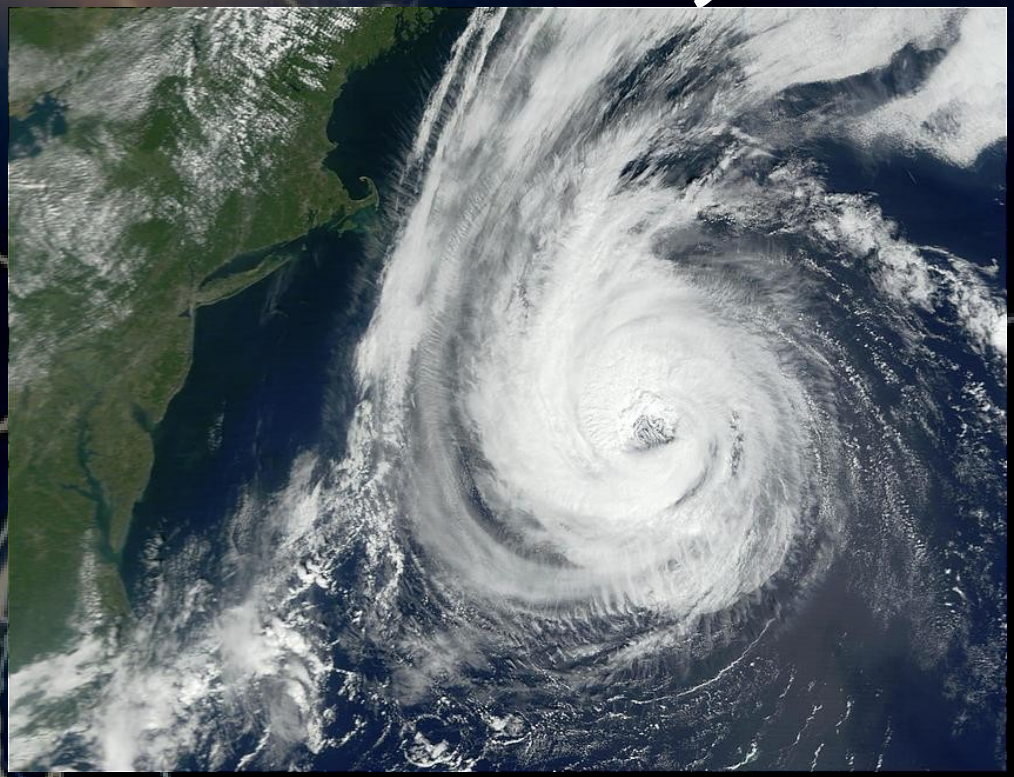



the product on the right (need to click) is a ¼ km


09/12/2001 1600-Z MODIS 250m True Color NRL Monterey

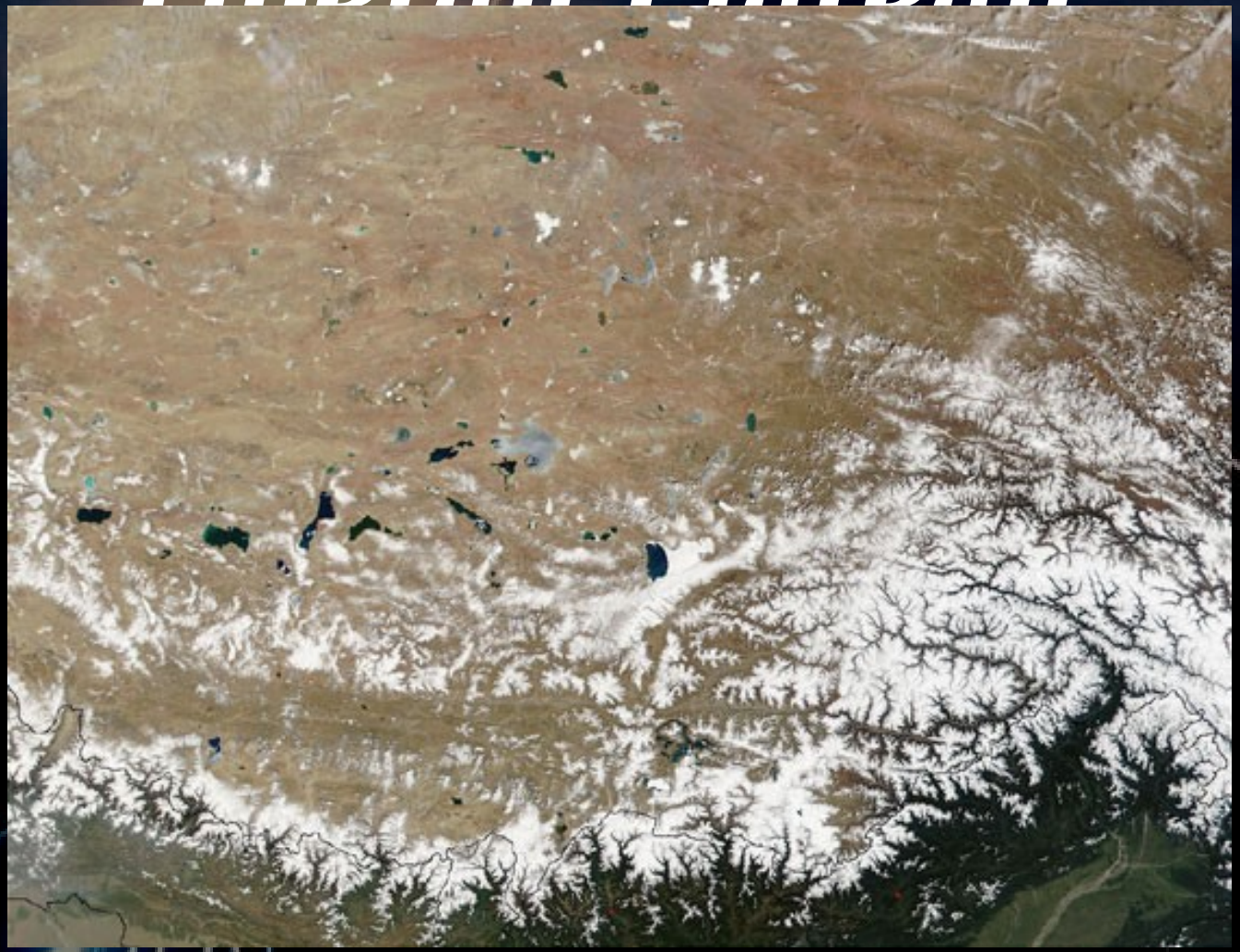
# MODIS True Color Shot

# September 11, 2001



Hurricane Erin, Image from NASA/GSFC
Land Rapid Response Team

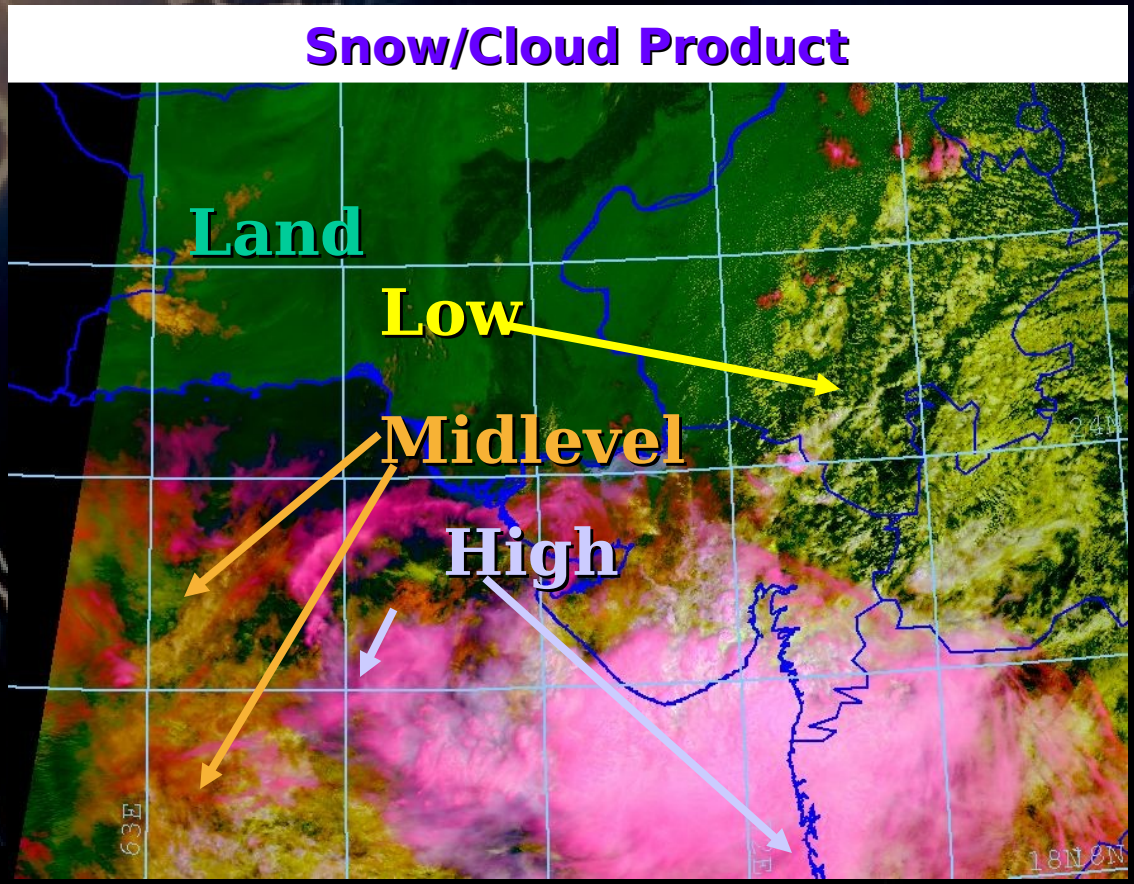
# MODIS Image of the Tibetan Plateau

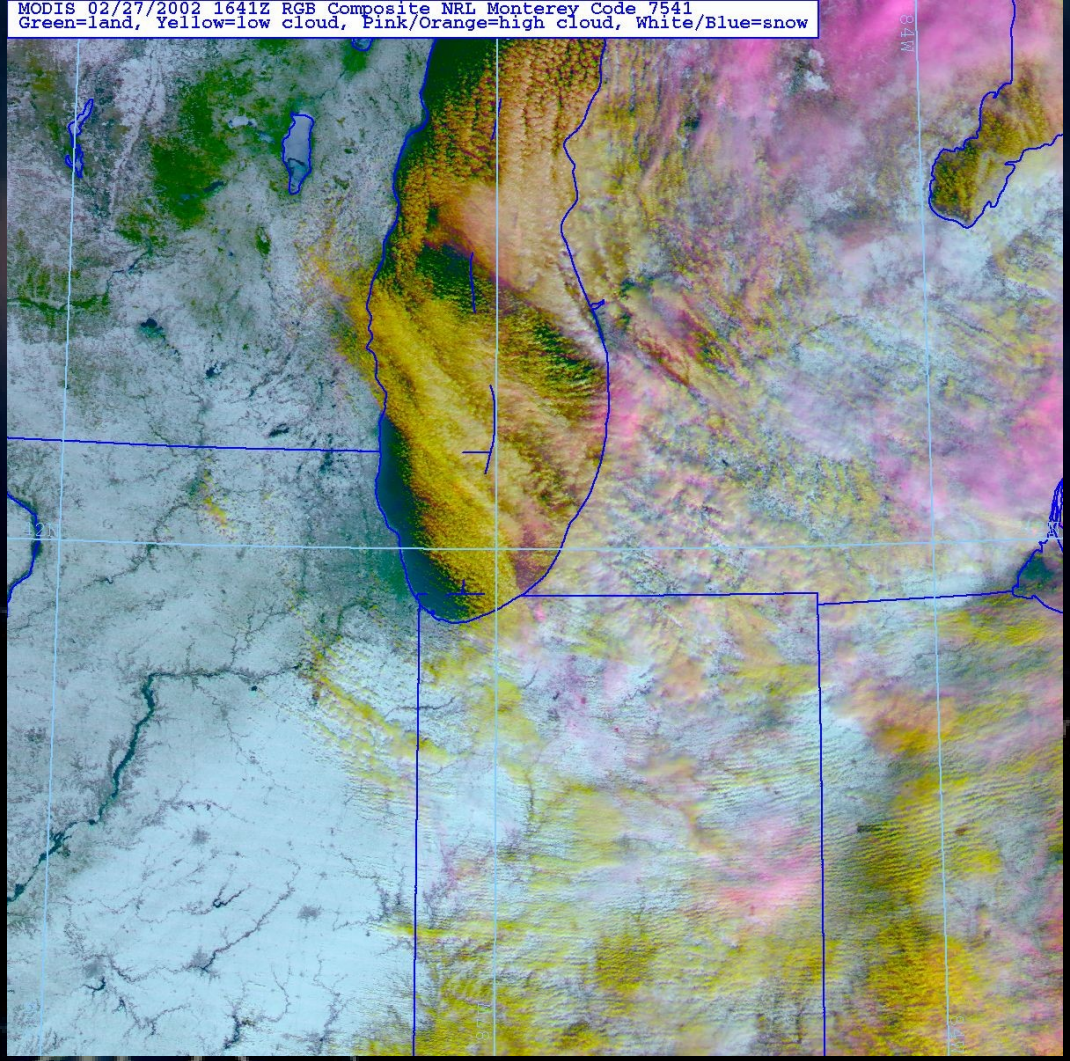


Credit: Jacques Descloitres, MODIS Land Rapid Response Team, NASA GSFC

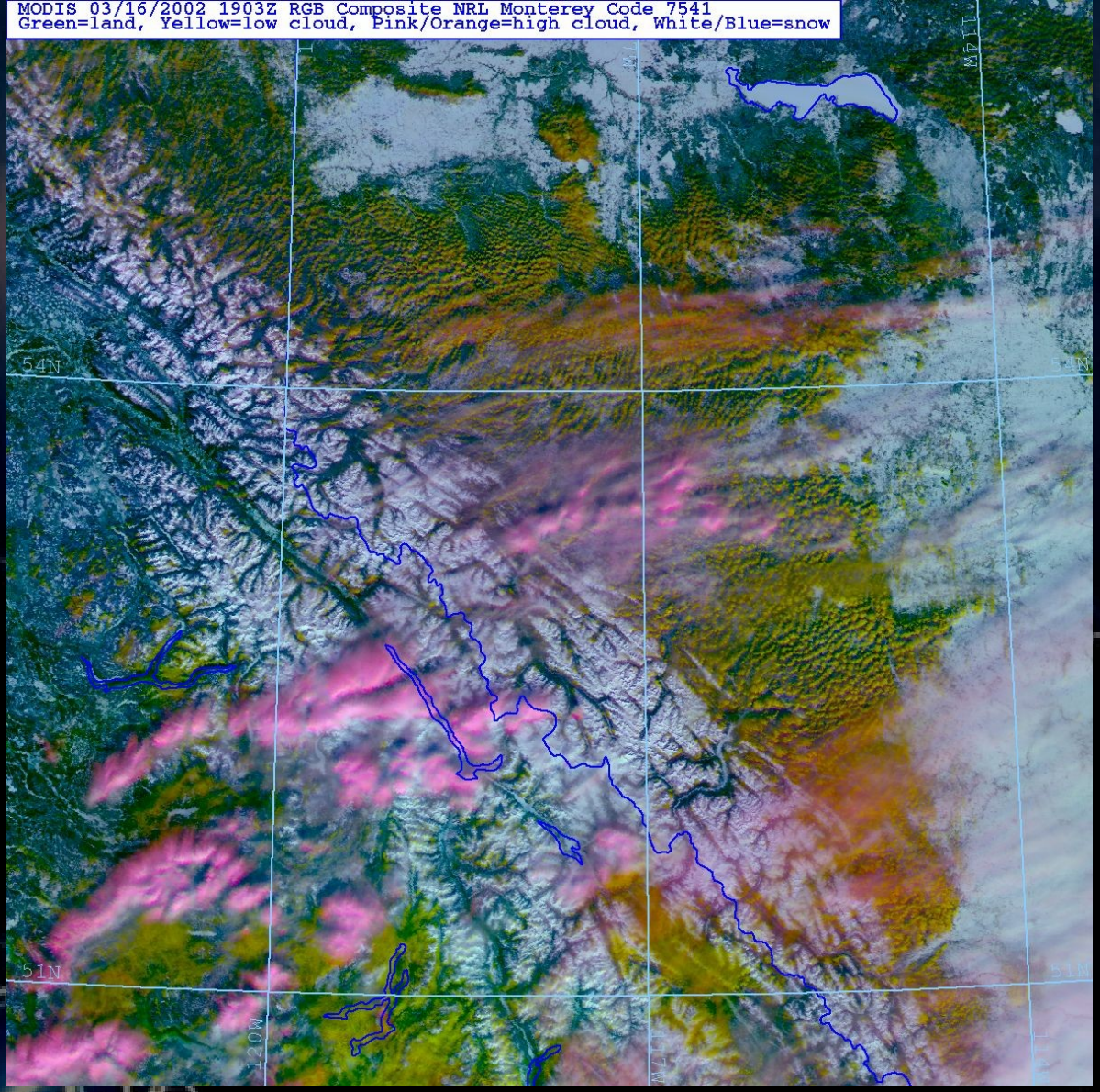
# Low-Cloud/High-Cloud/Snow

- Leverages existing technique applied to AVHRR (Fennimore, NOAA/NESDIS).
- Improvements to high, thin cloud detection using the MODIS 1.38μm channel.
- Snow-covered terrain (not shown) in this enhancement will appear blue/white.



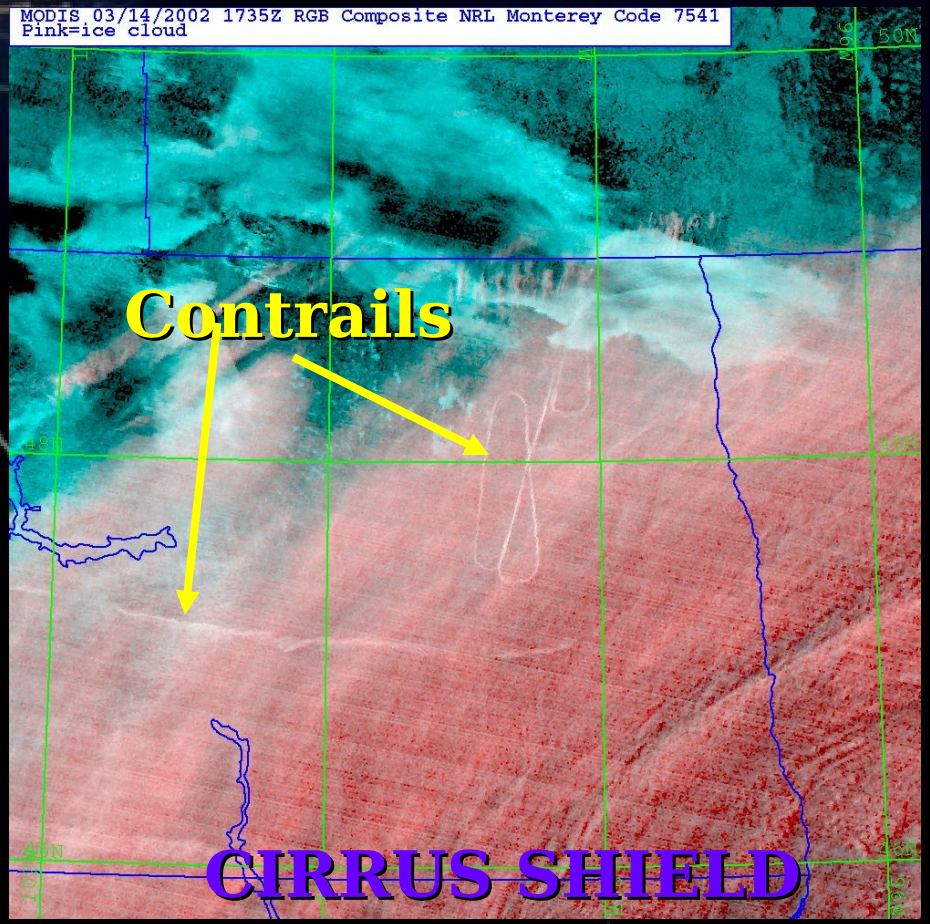

MODIS 02/27/2002 1641Z RGB Composite NRL Monterey Code 7541
Green=land, Yellow=low cloud, Pink/Orange=high cloud, White/Blue=snow

# Cumulus
# Cloud Streets


MODIS 03/16/2002 1903Z RGB Composite NRL Monterey Code 7541
Green=land, Yellow=low cloud, Pink/Orange=high cloud, White/Blue=snow
54N
51N
120W
114W

# Aircraft Contrail Detection

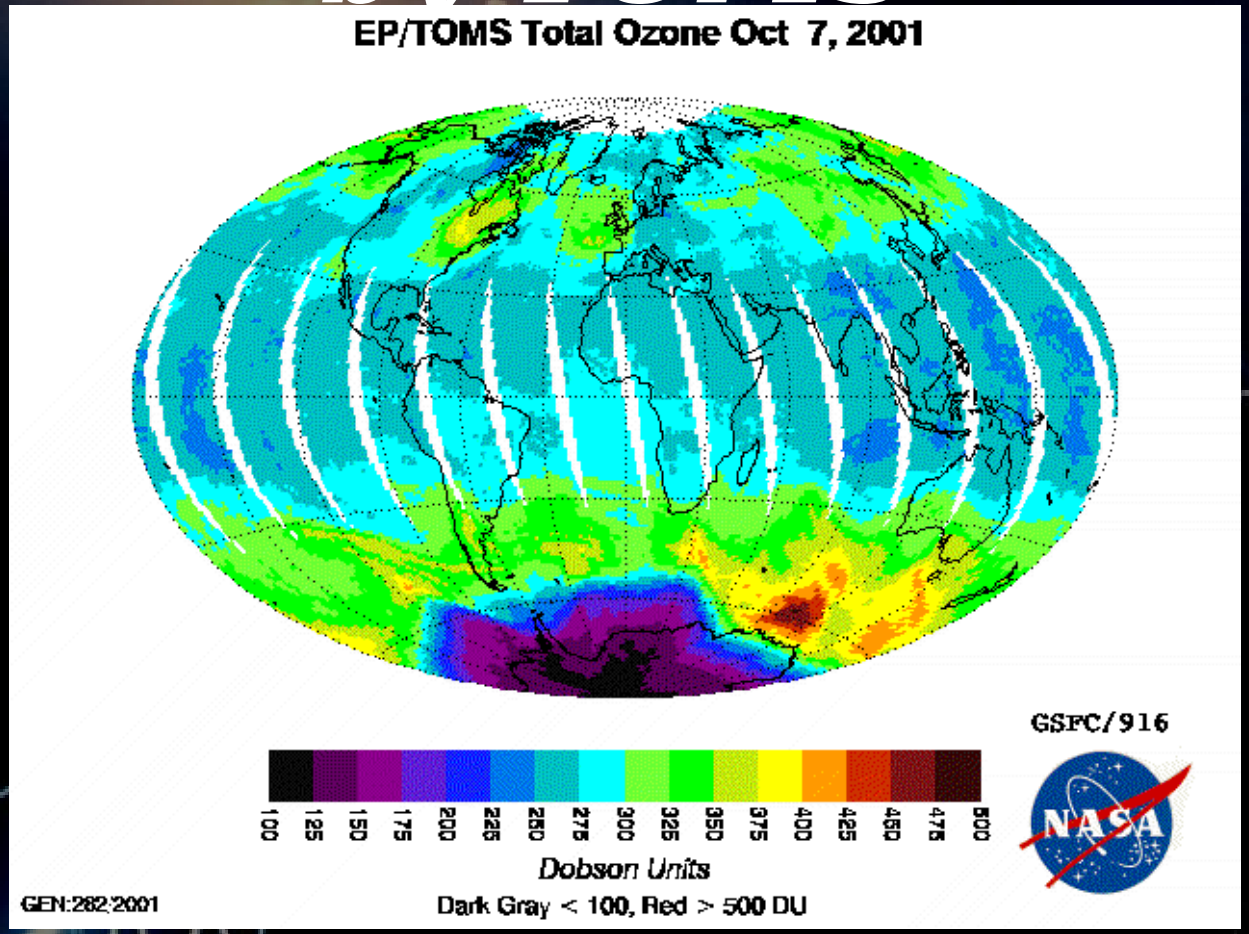
- Contrails form as a result of aircraft effluent condensation, leaving tell-tale signatures of aircraft position and trajectory.
- Contrails are often optically thin and display weak radiometric signatures in conventional monochromatic (single channel) satellite imagery.
- “Tri-spectral” cloud phase discrimination concept (e.g., Strabala et al., 1994) combined with split-window IR differencing at 1-km resolution to enhance contrails.



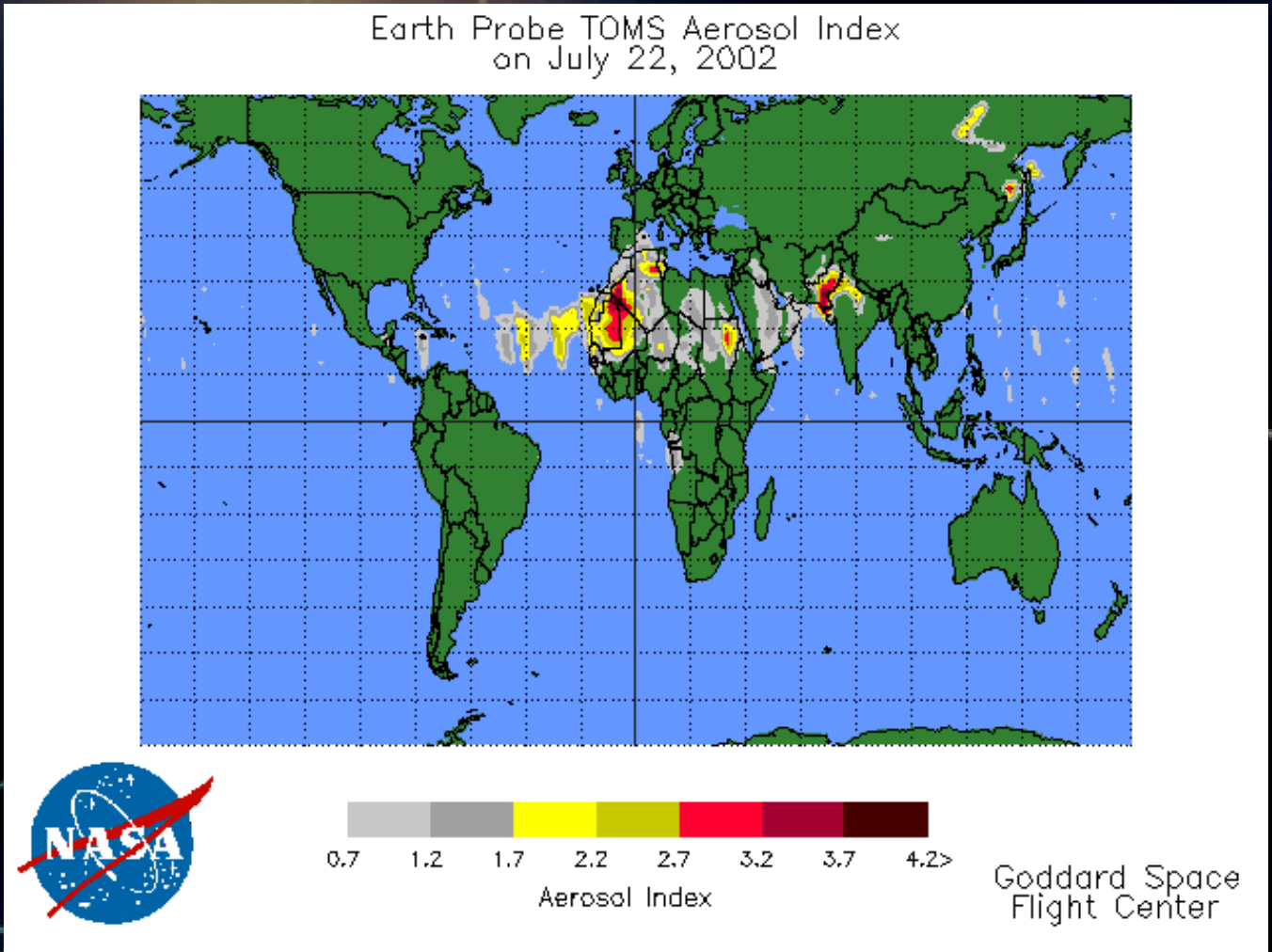
# Total Ozone Mapping Sensor (TOMS)

- TOMS main purpose is to monitor atmospheric ozone
- Also has a role in monitoring aerosols
- Six channels in the ultraviolet spectrum
- Can monitor air pollution and aerosols
- METOC application is for monitoring of  aerosols
- Degradation of aerosol index noticed in current instrument (Earth ProbeTOMS)
- Footprint size is about a degree, too coarse for detailed analysis

# Ozone Hole measured by TOMS



# TOMS Aerosol Index



# *Summary*

- LEO Advantages and Disadvantages
- LEO Characteristics
- Polar Orbiting LEO’s
- Operational Satellites

Questions

- APPLICATION:  Assign Review Exercise 7.

- EVALUATION:  Administer and evaluate Appraisal 302g.  Give the Written Test at the end of the unit.